PHASE I
RCRA FACILITY INVESTIGATION
FINAL REPORT

U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

PREPARED FOR:

U.S. STEEL
A UNIT OF USX CORPORATION

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LIST OF ACRONYMS

AOC	Area of Concern
ASTM	American Society of Testing and Materials
BP	Borrow Pit
CMS	Corrective Measures Study
COE	U.S. Army Corps of Engineers
CPT	Electronic Cone Penetrometer
DCC	Description of Current Conditions
DOI	U.S. Department of Interior
EP	Extraction Procedure
EPA	U.S. Environmental Protection Agency
FMTP	Finishing Mill Treatment Plant
GROWS	Geological Reclamation Operations and Waste Systems, Inc.
HASP	Health and Safety Plan
HSA	Hollow-stem auger
ID	Inside diameter
MCL	Maximum Contaminant Level
MODFLOW	USGS modular three-dimensional finite-difference groundwater flow model
MODPATH	USGS computer program to compute and display pathlines from MODFLOW
MSL	Mean Sea Level
NAD	North American Datum
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NPDWR	National Primary Drinking Water Regulations
PA DEP	Pennsylvania Department of Environmental Protection
PCBs	Polychlorinated biphenyls
PVC	Polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RPD	Relative Percent Difference
SMCL	Secondary Maximum Contaminant Level
SWMU	Solid Waste Management Unit
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TTP	Terminal Treatment Plant
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
USX	USX Corporation
WMNA	Waste Management of North America

EXECUTIVE SUMMARY

A Phase I RCRA Facility Investigation (RFI) has been conducted at U.S. Steel's Fairless Works, under Section 3008(h) of the Resource Conservation and Recovery Act (RCRA). The Phase I RFI has addressed the environmental setting at Fairless Works; the potential impacts of iron and steel slags used on site as fill material; the direction and rate of groundwater flow on the site, and the quality of that groundwater; and a preliminary evaluation of risk, including potential impacts to human health and aquatic ecosystems on the site and in the Delaware River.

Phase I RFI Results

The data and other information developed during the Phase I RFI was reviewed in a preliminary assessment of risk, which has led to certain conclusions regarding impacts or potential impacts to onsite and offsite receptors. These conclusions are summarized below.

Slag- Results of the sampling and analysis of slag, and groundwater from areas where slag has been placed at Fairless Works, demonstrate that slag is not a concern. This conclusion is supported by EPA's own risk assessment of slag, which determined that iron and steel slags are "low-hazard" and permanently excluded from regulation as a hazardous waste under RCRA, and by the PA DEP's concurrence with coproduct designation for the use of iron and steel slag as aggregate, fill, railroad ballast, and road base, etc. The slag at Fairless Works was processed and used for the same purposes that the PA DEP now formally endorses.

Groundwater- Groundwater has been identified as the critical medium for the potential migration of contaminants to offsite receptors. A groundwater model was developed to facilitate the design of a groundwater monitoring network; the network is heavily biased toward detection of any migratory contaminants at the perimeter. The 30 groundwater monitoring wells in the network were sampled for Appendix IX hazardous constituents (except PCBs and pesticides), and the potential for exposure to groundwater and surface water was assessed.

Based on the monitoring results, further investigation of groundwater quality in the confined aquifer is not warranted. Groundwater in the water table aquifer shows sporadic, low level, exceedances of screening criteria and background concentrations for a limited number of contaminants; the concentrations are sufficiently low that they will not result in exceedances of the DRBC water quality criteria after transport to and mixing with the Delaware River. Additional sampling is warranted in the water table aquifer, however, to confirm and further assess trends and conditions.

Surface Water- The ecological assessment for the Phase I RFI included field investigations of on site canals and on site open waters, and a review of historical data on biological and chemical sampling of the Delaware River. Investigations of the on site canals and on site open waters identified areas with ecological impacts that are potentially attributable to past site activities. However, both investigations suggest that any impacts are limited to the Fairless Works site. The review of historical data on surface water and sediment chemistry, water column and sediment toxicity, benthic communities, and fish communities all suggest that the Delaware River adjacent to and downstream of Fairless Works is relatively healthy and unimpacted by chemical releases from the site.

Additional RFI activities are recommended for the tidal portion of the Central Canal, and a Corrective Measures Study is recommended for the on site open waters habitats that show evidence of ecological impacts.

Soils and Waste Materials- Field inspections were made of soil and cover materials at SWMUs and AOCs, to assess conditions and the potential for exposure. No visual evidence of the erosion of cover materials was observed, except at a few locations where surface drainage from roads and open areas is directed into the on site open waters. The coarse size of the slag cover, its subsurface density, and the presence of vegetation, all mitigate against the potential for wind or water erosion. The potential for exposure through volatilization was found at only one borrow pit.

The potential for worker exposure to hazardous wastes or constituents was also assessed during these inspections. Waste materials in the SWMUs are generally covered, so this potential exposure pathway is not complete. The potential for unintentional worker exposure occurs at a small number of SWMUs and AOCs where some waste materials are uncovered. Although interim measures have been implemented at a number of these locations, final corrective measures are warranted at several borrow pits.

Recommendations for Additional Corrective Action Activities

Overall, the findings and conclusions of the Phase I RFI are positive, particularly with respect to potential threats to offsite receptors. No additional interim measures are necessary at this time to protect human health or the environment. However, Phase II RFI activities and corrective measures studies are recommended. These recommendations are a logical outgrowth of the findings and conclusions of the Phase I RFI, and represent the next priority for corrective action. The recommendations, described conceptually below, may be supplemented in the future, when additional RFI work has been completed.

Monitoring Well Network Sampling and Analysis- Groundwater sampling of the water table aquifer should be undertaken, to confirm the initial sampling results, address QA/QC issues, and determine whether there are any significant groundwater quality trends over time. Groundwater monitoring in the water table aquifer should include the analysis of filtered groundwater samples for arsenic, beryllium, cadmium, and nickel, which were detected above screening criteria and background concentrations, and selenium and zinc, which were detected above the DRBC water quality criteria.

Assessment and Investigation of VOCs in Northeast Quadrant- The Phase I RFI has shown that moderately elevated VOC concentrations in water table aquifer wells in the northeast quadrant of the site are not a threat to human health or the environment. However, an assessment should be conducted to determine whether additional water table aquifer wells are needed to evaluate the source of these VOCs, and whether the concentrations can be expected to decline over time. Selected wells in the northeast quadrant may be monitored for VOCs, if the assessment shows that additional monitoring is appropriate.

Central Canal Sediment Bioassays- Investigations of the tidal portion of the central canal should be undertaken to address benthic toxicity. Using bioassay techniques, it should be possible to determine whether the sediments are toxic, and if so, whether this toxicity is due to releases, anoxia, or naturally occurring metabolites.

Borrow Pits With Exposed Oil And Tar Residual Material- There are several SWMUs in which oil and tar residual materials are exposed. Rather than expending effort and time to further investigate conditions at these SWMUs, it is recommended that a Corrective Measures Study be conducted. The workplan for the CMS will include additional investigation, if needed, to evaluate alternatives. The alternatives will include, among other possibilities, the consolidation of the waste materials in a Corrective Action Management Unit (CAMU) at BP-35 or other location, covering the exposed waste materials, or removal of the exposed waste materials.

Borrow Pits With Impacted Open Waters- Open water areas in borrow pits were evaluated through a study of anuran population diversity. The protocol used in the study to determine impacted open waters was conservative, so that open waters may have been identified as potentially impacted, even though impacts may not be related to releases at SWMUs. Rather than expend effort and time to further distinguish the causes of impacts to the open waters in these borrow pits, it is recommended that a Corrective Measures Study be conducted for the ponds identified as impacted. The CMS evaluation of alternatives will include the provision of replacement habitat.

1.0 INTRODUCTION

1.1 BACKGROUND AND OVERVIEW

USX Corporation entered into a "Formal Administrative Order On Consent" (U.S. EPA Docket Number: RCRA-III-065-CA) under Section 3008(h) of the Resource Conservation and Recovery Act as amended, 42 U.S.C. Section 6928(h) for corrective action. The consent order includes requirements for the implementation of Interim Measures (IM), preparation of a Description of Current Conditions (DCC) and a Technical Approach document, preparation of RCRA Facility Investigation (RFI) Workplans and implementation of those workplans, and completion of a Corrective Measures Study (CMS) by USX Corporation for its facility (Fairless Works) in Fairless Hills, Pennsylvania. The effective date of the consent order was April 20, 1993.

The consent order requires that USX Corporation, which is referred to in this report by the name of its operating group U.S. Steel, submit a number of reports for EPA review and approval. The initial submissions provide the background and some of the details for corrective action at Fairless Works.

The first report submitted by U.S. Steel was the Description of Current Conditions. This three volume report was submitted, reviewed by EPA, revised, and approved by EPA. It contains substantial information about environmental conditions at Fairless Works, as of January 1994. It was used as a basis for the preparation of a "Technical Approach to the RFI/CMS" (Technical Approach) and a "List of Interim Measures" to be implemented.

The DCC includes information about the site and a preliminary assessment of the nature and extent of contamination, including an historical review and the identification and description of potential areas of concern (AOCs). The DCC describes waste management practices and the solid waste management units (SWMUs) on the site, as listed in the EPA RCRA Facility Assessment (RFA).

The Technical Approach to the RFI/CMS was submitted, reviewed by EPA, revised, and approved on March 30, 1994, with comments. The Technical Approach was based on information contained in the DCC and the scope of work for the RFI/CMS included as Attachments C and D of the Consent Order.

The Fairless Works site (the Site), shown on Figure 1-1, is large (3 square miles), complex, and diverse. There are 48 SWMUs and a number of AOCs at various locations on the site. The SWMUs include borrow pits that were used as a source of fill material for construction of the facilities at Fairless Works, and subsequently used for the management of waste materials and/or backfilled with slag, a by-product of the iron and steel making processes; and industrial wastewater treatment facilities, including the Finishing Mill treatment Plant (FMTP), the Rod Mill Settling Lagoon, and the Terminal Treatment Plant (TTP).

The Technical Approach provided a system for evaluation of the facility, and the opportunity for EPA and U.S. Steel to reach agreement concerning a conceptual strategy for corrective action before the submission of more detailed workplans.

In the Technical Approach, the RFI was divided into three phases, the first of which (Phase I) encompasses the entire site, permitting an evaluation of a number of significant site-wide issues including groundwater, impacts to aquatic ecosystems, and slag backfill. A more detailed description of the site environmental setting is also a part of the Phase I RFI. The scope of the Phase I RFI was determined by a workplan approved by EPA. Subsequent phases of the RFI activities (Phases II and III) are to address specific study areas, as defined and prioritized in this Phase I RFI report.

The consent order and the Technical Approach address Interim Measures. The Consent Order required the submission of an Interim Measure Workplan for the Terminal Treatment Plant Lagoons and borrow pit BP-35 within 30 days of the effective date. A workplan was submitted, reviewed by EPA, revised, and approved; the interim measures have been implemented and are monitored in accordance with the approved schedule, with the results reported to EPA. Two addendums to the Interim Measures Workplan for BP-35 were submitted, reviewed by EPA, revised and approved; these additional measures have also been implemented, to increase the effectiveness of the interim measures at BP-35.

In addition to the IM Workplan for BP-35 and the TTP Lagoons, the consent order required that U.S. Steel submit a list of proposed Interim Measures, shortly after completion of the DCC. The list included recommendations that Interim Measures be implemented at BP-13A and the Vac All Basin. Interim Measures Workplans were submitted to EPA, revised, and approved; the Interim Measures have been implemented and, in the case of BP-13A, the results are monitored and reported to EPA in accordance with the approved schedule. Subsequently, EPA determined that Interim Measures were necessary at BP10B. An Interim Measures Workplan was submitted, reviewed by EPA, and approved, and the interim measures have been implemented. Implementation Reports for the Interim Measures at BP-10B and the Vac All Basin have been submitted to and approved by the EPA.

The interim measures for BP-35, the TTP Lagoons, BP-13A and BP-10B were implemented to reduce the potential for wildfowl and other wildlife to come in contact with waste materials exposed in or around the SWMUs. The interim measures have included fencing, netting, bird deterrents, pumping surface water runoff, and covering exposed materials. While these measures have been effective, they are of a temporary nature, to be utilized until final corrective measures are determined. The interim measures continue to be maintained and monitored, and their conditions are reported to EPA.

1.2 PHASE I RCRA FACILITY INVESTIGATION

A workplan for the Phase I RFI was submitted, reviewed by EPA, revised, and approved with conditions. The Phase I RFI goals include assessing site-wide issues, identifying needs, and establishing priorities for investigations, and studies that may follow.

The scope of work for the Phase I RFI addressed four site-wide issues:

1. The environmental setting
2. Slag and the potential impacts of slag
3. The direction, rate and quality of groundwater flow
4. A preliminary evaluation of risk to human health and aquatic ecosystems

The environmental setting at Fairless Works was presented in the DCC. However, the Phase I RFI included activities, such as soil sampling and analysis, stratigraphic borings, slug testing wells, and other tasks which gathered site specific data, providing additional detail and confirming or establishing specific conditions. The Phase I RFI report presents this additional information.

As pointed out in the DCC, groundwater flow provides the most significant potential migration pathway for contaminants. For this reason, groundwater investigation and modeling is a large part of the Phase I RFI work scope. A groundwater model was used to establish a monitoring network, consisting of existing and new monitoring wells; the selection of existing wells and location of new wells for the network was based on particle-tracking from the SWMUs and AOCs on the site, using the groundwater model.

A number of milestone groundwater modeling submissions were made to EPA for its approval. A report containing the model calibration criteria was reviewed and approved by EPA. The calibrated model was presented in an "Interim Report" (along with other information generated during the Phase I RFI) which was reviewed by EPA, revised, and approved. The model was verified through a second round of groundwater level measurements, and the calibration was modified to fit the additional data set. The verification results were reported in a "Verification Report" along with particle-tracking and recommendations for a groundwater monitoring well network. The Verification Report was reviewed by EPA, revised, and approved. A comprehensive presentation of the approved groundwater model, particle-tracking, and monitoring well network is included in this Phase I RFI report.

Aquatic habitat on site, in the borrow pits and canals, as well as the Delaware River which borders the site on three sides, are potential pathways for contaminant migration and/or receptor exposure. Open water aquatic habitat has developed in borrow pits, which were partially backfilled with slag and other material. The habitats in these SWMUs are more likely to have been impacted than other such habitats on the Site, and the population of anurans in the ponds was assessed as a method for determining the potential for any such impacts. The results of this study are included in this Phase I RFI report.

The three on site canals now transport non-contact cooling water and stormwater runoff from the facility. Water quality discharging from the canals is monitored through NPDES-permitted outfalls. The canals, although they are not intended to serve as aquatic habitats, are a potential pathway for migration of contaminants in sediments to the Delaware River. The population of benthic organisms at various locations in the canals, as compared to control sites, was used to qualitatively assess impacted sediment. The results of this study are included in this Phase I RFI report.

The size of the River, coupled with complex hydrology and the upstream sources of contaminated sediments which are likely to settle at the head end of the Estuary, makes any assessment of Delaware River water and sediment quality at Fairless Works a difficult matter. Available data concerning the Delaware River and potential impacts from Fairless Works is reviewed, evaluated, and discussed in this Phase I RFI report.

The fourth site-wide issue addressed in the Phase I RFI is slag, a by-product of steel making found in many areas of the site. Slag was backfilled in the borrow pits, which are designated as SWMUs. Slag was evaluated by EPA in 1990 on a national scale, including slag at Fairless Works. This Phase I RFI report incorporates a review of the literature concerning slag. Site specific data concerning slag backfill at Fairless Works is also presented in this report.

The data and other information developed during the Phase I RFI is reviewed in a preliminary evaluation of risk, which is included in this Phase I RFI report. The Phase I Report presents recommendations for additional work that may be appropriate at Fairless Works, based on this assessment.

2.0 ENVIRONMENTAL SETTING

2.1 SOILS

A general description of the surface soil types identified at Fairless Works was presented in the DCC. A summary of these soil descriptions is included below, and a map showing the location of these various soil types is included as Figure 2-1.

Representative surface soil samples were collected as part of the Phase I RFI work, in order to evaluate background soil conditions and to determine the site-specific properties of the four soil types found on site: Urban Land; Urban Land-Howell Complex; Pope Loam; and Marsh sediments. However, most of the SWMUs and AOCs located on the site are on urban land, and the dominant soil type in and around these units is slag, which is discussed in detail in Section 4.0 of this report.

Urban Land is the predominant soil type found at Fairless Works. Most Urban Land was created on upland terraces; however, some is present on the floodplain. Generally, the areas are irregular in shape. The surface soils and foundation materials are highly variable. Most areas have been leveled and the original soil material removed, disturbed or filled over prior to construction. Industrial structures cover much of the urban land surface. Slag is the predominant surface soil material within this soil type.

The Urban Land-Howell Complex is the second most predominant soil in areal extent at Fairless Works. This complex is 60 percent Urban Land, 35 percent Howell silt loam, and 5 percent other soils. It is found in semi-builtup irregular areas on terraces.

The Howell silt loam is found on 0 to 3 percent slopes. This soil is found on broad, uniform sides of terraces. The soil profile is a surface layer of dark brown and dark grayish brown silt loam greater than 9 inches thick. The subsoil is greater than 33 inches thick. Generally, the upper 20 inches is brown, silty clay loam and clay loam, and the lower 15 inches is brown, sandy clay loam and gravely-clay loam that extends to a depth of 50 inches.

The Pope loam (terrace) is found on 0 to 3 percent slopes. This soil is mainly on broad low terraces. It lies above the present level of flooding. The Pope loam (terrace) is found in the northeast corner at Fairless Works, bordering on the Delaware River. The Pope loam is derived from weathered shale, sandstone, quartz, and limestone. A representative profile of the Pope loam (terrace) shows the surface layer is a dark brown loam about 10 inches thick. The subsoil is 39 inches thick; the upper 13 inches is brown loam and very fine sandy loam, and the lower 26 inches is brown and dark yellowish-brown fine sandy loam. The substratum is dark yellowish brown and dark grayish-brown, very gravely loamy sand and gravely sand that extends to a depth of 80 inches.

The Fallsington silt loam, gravely subsoil variant, is found on the southern end of Biles Island. Most of this soil is in slight depressions and at the base of low slopes. A representative profile of the soil in a wooded area includes 2 inches of organic material covering the surface, a grayish-brown silt loam surface layer about 7 inches thick, and the subsoil, about 43 inches thick. The upper 8 inches of the subsoil is light gray and very pale brown gravely silt loam and gravely silty clay loam that has predominant brown, yellowish-red, and white mottles. The next 20 inches is gray gravely sandy clay loam that has distinct light gray, reddish-yellow, brown, and white mottles. The lower 15 inches is brown mottled gravely sandy clay loam.

2.1.1 Surface Soil Samples

On October 27 and 28, 1994, 10 soil samples were collected from the four soil types identified at Fairless Works; the sample locations are shown on Figure 2-2. Composite soil sampling procedures were used to provide representative sample results. Sample locations were chosen in relatively undisturbed areas, avoiding slag backfill.

The samples were collected as follows: four samples were obtained in areas classified as Urban Land and designated Ub-1 to Ub-4; two samples were collected from Urban Land-Howell Complex and designated Uh-1 and Uh-2; two samples were collected from Pope Loam and designated PpA-1 and PpA-2; and two samples were collected from Marsh sediments and designated Mh-1 and Mh-2. The majority of the Site is covered by Urban Land soil, and so a greater number of composite soil samples was collected from this soil type.

Soil samples were analyzed for parameters listed in Table 2-1.

Soil moisture, particle size distribution, Atterberg limits, and remolded porosity tests were completed by Valley Forge Laboratories, Inc. in Devon, Pennsylvania. The remolded porosity method provides estimated values of in-situ porosity.

On September 20, 1996, 10 surface soil samples were collected at the October 1994 sampling locations, for saturated and unsaturated hydraulic conductivity analysis. Sample designations were as described above. The soil types, number of samples, and analytical methods are listed in Table 2-2.

Prior to sample collection, the *in-situ* (undisturbed) density and water content of the soil at each location was measured using a Troxler nuclear density gauge as specified in standard test method ASTM D2922. Field measurements and laboratory saturated and unsaturated hydraulic conductivity tests were completed by Valley Forge Laboratories, Inc. in Devon, Pennsylvania. The 10 samples were remolded in the laboratory at their field-measured water contents to their field-measured densities, saturated, and tested for permeability using either Army Corps of Engineers methods (sandy soils) or Triaxial permeameter methods (clay soils). Specific gravity was assumed to be 2.65 and 2.70 grams per cubic centimeter (g/cc) for sandy and clayey soils, respectively.

Results

Table 2-3 presents the results of chemical and physical analyses of the surface soil samples. The associated laboratory analytical support documentation is included in Appendix 2-1. The sample results are compared to data presented in the Soil Survey of Bucks and Philadelphia Counties, Pennsylvania (USDA, 1975). However, the USDA only provides soil physical properties data for the Pope Loam.

Grain size distribution results indicated that Urban Land soil samples consisted of silty sand with gravel. In general, only about 20 percent of the Urban Land soil samples consisted of silt- and clay-sized particles. The remolded porosity of Urban Land soil samples ranged from 25.9 to 26.9 percent. The natural moisture content in the Urban Land soil samples ranged from 5.6 to 8.1 percent. The total organic carbon (TOC) content of Urban Land soil ranged from 2,290 to 11,600 milligrams per kilogram (mg/kg). Soil pH levels ranged from 6.60 to 7.50 standard pH units (std. units). The cation exchange capacity of Urban Land soil samples ranged from 3.0 to 4.3 milli-equivalents per 100 grams (meq/100 grams). Saturated hydraulic conductivity values ranged from 2.49×10^{-7} to 1.11×10^{-5} centimeters per second (cm/sec), while unsaturated hydraulic conductivity values (at field-measured water content and density) ranged from 9.24×10^{-8} to 3.58×10^{-5} cm/sec.

The Urban Land-Howell Complex soil samples were classified by grain size distribution as predominantly fine grained material, either silt with sand or sandy low-plasticity clay. The remolded porosity of Urban Land-Howell Complex soil samples ranged from 34.1 to 40.0 percent; natural moisture content ranged from 18.2 to 22.6 percent. The TOC content of Urban Land-Howell Complex soil samples ranged from 2,270 to 9,460 mg/kg. Soil pH levels ranged from 6.00 to 6.10 std. units. The cation exchange capacity of Urban Land-Howell Complex soil samples ranged from 5.1 to 7.8 meq/100 grams. Saturated hydraulic conductivity values ranged from 4.44×10^{-8} to 1.66×10^{-7} cm/sec. *In-situ* unsaturated hydraulic conductivity values (at field-measured water content and density) ranged from 3.01×10^{-8} to 7.98×10^{-8} cm/sec.

Grain size distribution results indicated that Pope Loam soil samples consisted of low plasticity silt with 20 to 40 percent sand. According to the USDA (1975), the upper 12 inches of a representative sample of Pope Loam consisted of approximately 40 percent sand, 40 percent silt, and 20 percent clay. Natural moisture content of the site-specific samples ranged from 17.5 to 18.7 percent and the porosity ranged from 34.7 to 37.8 percent.

The TOC content of the Pope Loam soil samples ranged from 1,730 (0.17 percent) to 6,200 mg/kg (0.62 percent). The USDA reported TOC levels in surficial Pope Loam ranging from 0.23 to 0.83 percent. Soil pH levels ranged from 5.10 to 5.50 std. units. The cation exchange capacity of the Pope Loam soil samples ranged from 4.1 to 5.3 meq/100 grams.

The USDA reported pH ranging from 5.0 to 5.4 std. units and cation exchange capacity ranging from 3.5 to 6.0 meq/100 grams. Saturated hydraulic conductivity values ranged from 8.81×10^{-8} to 2.18×10^{-7} cm/sec. *In-situ* unsaturated hydraulic conductivity values (at field-measured water content and density) ranged from 2.95×10^{-8} to 6.58×10^{-8} cm/sec. The USDA characterizes the Pope Loam as moderately well drained, and presents an average field-estimated permeability value of 3.0×10^{-3} cm/sec. In general, the physical properties of the Pope Loam samples collected at Fairless Works are similar to USDA values.

Marsh sediment samples consisted of silty sand. The silt content ranged from 25 to 40 percent. The porosity ranged from 59.2 to 67.6 percent, and natural moisture ranged from 53.6 to 79.6 percent. The TOC content of Marsh sediment samples ranged from 93,800 to 105,000 mg/kg. The pH level of the sediment was 6.10 std. units. The cation exchange capacity of Marsh sediments ranged from 10.4 to 12.1 meq/100 grams. Saturated hydraulic conductivity values ranged from 4.73×10^{-6} to 9.17×10^{-6} cm/sec. *In-situ* unsaturated hydraulic conductivity values (at field-measured water content and density) ranged from 4.63×10^{-6} to 6.38×10^{-6} cm/sec.

2.2 GEOLOGY

2.2.1 Regional Geology

The geology of the Atlantic Coastal Plan consists of unconsolidated Quaternary and Cretaceous age sediments that lie upon a basement of early Paleozoic and older rocks. The stratigraphic units in the vicinity of Fairless Works can be separated into four general groups: pre-Cretaceous crystalline basement rocks; late Cretaceous unconsolidated clays, sands, and gravels; Pleistocene sands and gravels; and recent river floodplain deposits. A generalized geologic column for the coastal plan of southeastern Pennsylvania is presented in Figure 2-3.

Pre-Cretaceous

The basement rocks of the Piedmont Province are an assemblage of fine- to coarse-grained, crystalline, bonded, metamorphosed sedimentary and igneous rocks of the Glenarm Series. The rocks are divided into three distinct lithologies including a hornblende gneiss, granite gneiss, and a sequence of alternating micaceous schists and quartzite. In southeastern Pennsylvania, the basement rocks are predominantly micaceous and quartzose, and are assigned to the Wissahickon Formation. Cleavage and jointing are conspicuous and the color varies from yellowish-gray to brownish-black. Age dating of the Wissahickon Formation suggests that these rocks formed during the early Odovician Period at least 450 million years before the present (Greenman, *et al.*, 1961).

The upper surface of the basement rock is frequently weathered to a residual soil (saprolite) that ranges in thickness from several feet to several tens of feet. The upper few feet are distinguished by a soft, gray, extremely micaceous clay that becomes firmer and more granular with increasing depth. The *in situ* weathered, micaceous, saprolitic clay will retain the fabric and structure of the parent rock (Wissahickon Formation). Beneath the partly disintegrated zone, the parent rock is a medium to coarsely crystalline, well foliated mica schist.

Cretaceous

A late Cretaceous unconsolidated sedimentary sequence rests unconformably on the crystalline basement rock. This sequence consists of layers of highly permeable sands and gravels alternating with low permeability silt and clay layers. The sedimentary sequence was formed primarily by non-marine depositional processes. These deposits represent river channel, floodplain, and estuary sedimentation. The Cretaceous sediments are subdivided into the Raritan and Magothy Formations. The Raritan Formation is partially exposed in southeastern Bucks County while the Magothy is absent.

The Raritan Formation consists of alternating beds of non-marine clay, sand, and gravel that occupy the stratigraphic interval between the consolidated pre-Cretaceous rocks below and the Magothy Formation above. The Raritan Formation can be readily distinguished from the overlying Magothy Formation on the basis of fauna and lithologic evidence.

In southeastern Pennsylvania, the Raritan Formation consists of a sequence of non-marine deposits representing three cycles of sedimentation. Each cycle begins with a series of coarse detrital deposits and closes with a series of silts and clays. This sequence almost duplicates the section exposed in the type locality in New Jersey where the Raritan was subdivided into seven members. In ascending order, these members include the Raritan fire clay, the Farrington sand, the Woodbridge clay, the Sayreville sand, the South Amboy fire clay, the Old Bridge sand, and the Amboy stoneware clay.

Each of these members can be correlated with equivalent units in Pennsylvania, with the exception of the lower-most member, the Raritan fire clay, which is not easily recognized because the clay that occupies the same stratigraphic interval in the Pennsylvania section is believed to represent a residual clay (saprolite) derived from the mechanical disintegration of the underlying crystalline rocks. In this report, the three clay members of the Raritan will be called, in ascending order, the lower, middle, and upper clay members. Therefore, in ascending order, the members of the Raritan formation in southeastern Pennsylvania are the Farrington sand, the lower clay, the Sayreville sand, the middle clay, the Old Bridge sand, and the upper clay. The correlation of the six members is based solely upon the similarities in texture and sequence of Raritan strata in Pennsylvania and New Jersey, and does not necessarily mean that the individual strata can be traced as continuous lithologic units.

The Farrington sand member is the basal sand member of the Raritan Formation in southeastern Pennsylvania, occupying the lowermost part of the pre-Cretaceous channels carved into the underlying crystalline rocks (Greenman, *et al.* 1961).

The Farrington sand member consists of predominantly coarse sand and fine gravel that grade upward into medium-to-fine grained sand containing a few beds of white clay. The color of the sand varies from yellowish gray to pale yellowish brown. Generally, the coarse sand and fine gravels are fairly well sorted, but not as well sorted as the finer-grained materials (Greenman, *et al.*, 1961).

The thickness of the Farrington sand member varies greatly in southeastern Pennsylvania. The member is thickest in the axial parts of the troughs, and thins rapidly toward the margins. The sand attains a maximum thickness of approximately 90 feet, but in most areas of occurrence in southeastern Pennsylvania, it rarely exceeds 60 feet in thickness (Greenman, *et al.*, 1961).

The lower clay member is composed mainly of a trough clay forming a nearly continuous bed of clayey material separating the underlying Farrington sand member from the overlying Sayreville sand member (Greenman, *et al.*, 1961). Generally, the lower clay occurs in the same bedrock channels as the Farrington sand member, but the distribution of the clay is somewhat different. Along the margins of the troughs, the Farrington extends beyond the limits of the lower clay. The absence of the lower clay near the heads of the troughs indicates that it was subject to stream erosion immediately following the deposition of the clay. The trough clays are brick red in color, in contrast to the gray color of the softer materials (Greenman, *et al.*, 1961).

The lower clay rests unconformably upon either the Farrington sand member or the residual clay (saprolite) of the crystalline rock. Similarly, the upper contact of the member is distinct where the clay is directly overlain by the Sayreville sand member of the Raritan (Greenman, *et al.*, 1961). The thickness of the lower clay differs from place to place due to the irregularities of the surface upon which it was deposited. For the most part, the thickness ranges between 20 and 40 feet.

The Sayreville sand member of the Raritan Formation consists of a sequence of light-colored, very fine- to coarse-grained sand beds and a few beds of light-gray clay. The predominant color of the sand is pale yellowish-brown to orange. Most of the sediments are fairly well sorted, and the grains are commonly subangular to subrounded. Characteristically, the nominal grain size decreases away from the heads of the depositional troughs, indicating the relative direction of movement of the depositing medium. Although the Sayreville is a persistent depositional unit, previous drilling logs give evidence that the sequence of beds is not altogether uniform from place to place. This suggests that the material was deposited in lens-shaped masses by shifting currents (Greenman *et al.*, 1961). The thickness of the Sayreville sand member ranges from not present to a maximum of 49 feet. Generally, the thickness is greatest near the axes of troughs in the underlying bedrock.

The middle clay is the most extensive clay member of the Raritan Formation in Pennsylvania. The upper surface of the clay is characterized by several elongated depressions oriented parallel to the trend of the underlying bedrock channels. Most of these irregularities are believed to be due to erosion that occurred contemporaneously with the deposition of younger deposits. A nearly uniform slope of approximately 40 feet per mile to the southeast is discernible where the surfaces of the clay are least channeled. This slope probably approximates the attitude of the strata composing this member.

The lithology of the middle clay is much less variable than that of other clay members of the Raritan Formation. For the most part, the middle clay member is composed of stiff, red and white, clay with a uniformly massive texture. It commonly contains relatively little sandy material, but a few thin streaks or lenses of fine-grained sand have been noted, particularly in its middle and upper parts. Locally, the base of the member is marked by a conspicuous bed of lignite. In general, the top and bottom of the clay in the subsurface can be identified readily from well logs, except where the member lies directly upon other Raritan clays. In such places, it is difficult to distinguish the contacts because of the lithologic similarity of the individual clay members (Greenman *et al.,* 1961).

The thickness of the middle clay, similarly to that of the lowest clay, differs considerably from place to place owing to irregularities in the erosional surfaces that occur above and below the member. Within Southeastern Pennsylvania, the thickness commonly exceeds 20 feet, and ranges from not present to about 60 feet (Greenman, *et al.*, 1961).

The Old Bridge sand member unconformably overlies the middle clay. Although it does not crop out at the surface in Pennsylvania, the Old Bridge sand underlies much of the Coastal Plain area in southeast Bucks County. For the most part, the Old Bridge occupies erosional depressions or scour channels in the underlying middle clay. Apparently, the Old Bridge sand member was deposited by the same streams that scoured the channels in the clay; hence, it is assumed that erosion of the clay took place contemporaneously with the deposition of the sand. In a few localities, the underlying middle clay was completely removed and the Old Bridge was deposited directly upon deposits older than the middle clay (Greenman, *et al.*, 1961).

The Old Bridge sand member consists mainly of medium- to coarse-grained sand and contains minor amounts of fine to very fine sand. Beds of gravel are common, particularly at the base of the member. The predominant color is light gray to yellowish-brown. In general, the material comprising the Old Bridge is fairly well sorted, and individual grains appear to be angular or subangular (Greenman, *et al.*, 1961).

The thickness of the Old Bridge sand member is greatest along the axis of the depressions in which the sand accumulated. Away from these axes, the thickness gradually diminishes until the sand pinches out. It rarely exceeds 35 feet except near Turkey Hill in Bucks County, where as much as 100 feet of sand has tentatively been identified as Old Bridge (Greenman, *et al.*, 1961).

The upper clay is the uppermost member of the Raritan Formation. It is not an extensive deposit in Pennsylvania, but it does occur in the subsurface in a few localities in Bucks County. Where the upper clay is present in the subsurface, it overlies the Old Bridge sand member, separating the latter from the overlying Pleistocene deposits or from the Magothy Formation, if present.

The upper clay attains a thickness of 25 feet in Bucks County. It consists of light gray, more or less sandy clays; dark gray carbonaceous clays; and massive, red, white, and yellow clays (Greenman, *et al.*, 1961).

Quaternary

The Cretaceous sediments of the Coastal Plain of Pennsylvania are completely buried by Pleistocene deposits consisting of sand, gravel, and clay. Lockwood and Meisler (1960) subdivided the Pleistocene in the Coastal Plain of Bucks County into Wisconsinan and Illinoian stages, which are separated by a period of weathering and erosion corresponding to the Sangamon interglacial stage (Greenman, *et al.*, 1961).

In Bucks County, the maximum thickness of the Pleistocene deposits is about 60 feet, while the typical thickness is approximately 30 feet. The older, Illinoian-age, sediments are intensely weathered compared to the Wisconsinan sediments. Glacial erratics (boulders) weighing as much as several hundred pounds are found in the Illinoian in the Morrisville area. Some of the boulders have flattened solelike surfaces on which faint glacial striations are common. The deposits of Wisconsinan age consist of poorly sorted, gray sand and gravel comprising material ranging in size from fine-grained sand to glacial erratics weighing several hundred pounds of diverse lithologies. Many of the boulders in the Wisconsinan are also soled and show strong glacial striations (Greenman, *et al.*, 1961).

Recent

Recent floodplain deposits consist of organic, dark gray mud, silt, and fine sands that underlie the channels and tidal flats of the Delaware River and its principal tributaries. The recent sediments occur as a thin veneer of fine-grained material that overlie other deposits. In some cases, these materials form a confining bed over the Pleistocene deposits.

2.2.2 Stratigraphic Borings

Twelve electronic cone penetrometer (CPT) borings to the top of bedrock were proposed to determine the nature and extent of the various stratigraphic units beneath Fairless Works. In addition to the CPT investigation, two deep borings and samples to identify the physical properties of the subsurface materials and to verify the CPT results were proposed. The objectives were as follows:

- Determine the vertical and horizontal extent, thickness, and orientation of the hydraulic units beneath the Site
- Confirm the interconnection between the Trenton Gravel and the Old Bridge Sand
- Confirm the presence of the lower-most water-bearing unit of the Raritan Formation (Farrington Sand)

- Provide input data for the numerical groundwater flow model

- Determine subsurface conditions in a bedrock channel below the site

Subsurface conditions encountered at the initial CPT boring locations prevented efficient use of CPT technology. A thick layer of very fine grained sand and clay units were prevalent beneath the site, and when compacted by the advancing tip of the piezocone, these layers formed extremely dense, impenetrable barriers, which prevented continuous down-hole advancement of the CPT equipment. For this reason, the CPT method was abandoned in favor of more conventional hollow stem auger (HSA)/mud-rotary drilling and split-spoon sampling techniques. EPA was notified of this change of approach by letter dated December 19, 1994.

Twelve borings were drilled to the top of the bedrock surface during the period between October 31, 1994 and January 13, 1995. The boring locations are shown on Figure 2-2. The borings were completed using a combination of HSA and mud-rotary drilling methods. Samples were collected at 5-foot intervals at each boring location using a 2.0-inch inside diameter (ID) split-spoon soil sampling device. All down-hole drilling and sediment sampling equipment was steam cleaned prior to use at each location to prevent potential cross-contamination. A geologist described the sediments in accordance with the Unified Soil Classification System (USCS), and the results were recorded in a bound field notebook. The lithology and standard penetration test results (blow counts) are provided on the boring logs in Appendix 2-2.

Deep Boring No. 8 (DB-8), located near the Delaware River in the southwestern portion of the site, was completed as a groundwater monitoring well screened in the Farrington Sand. This well was constructed to provide hydraulic head data in the confined aquifer. The well was designated MW1-22-173, and its location is shown on Figure 2-2. Well construction details are provided in Appendix 2-3. The well was developed to a turbidity-free discharge using a submersible pump.

After completion of the soil borings, the ground elevations and locations were surveyed by a Pennsylvania-licensed land surveyor. The ground elevation was surveyed to the nearest 0.01 foot in accordance with the 1929 National Geodetic Vertical Datum (NGVD); horizontal coordinates were measured to the nearest 0.01 foot based on the 1983 North American Datum (NAD) horizontal control. The survey results are provided in Appendix 2-4.

2.2.3 Stratigraphic Sections

Boring logs and survey data were reviewed and compiled into a series of cross sections showing the thickness and horizontal extent of the major sedimentary units beneath the Site. In addition to the deep borings, historical data obtained from soil borings completed during previous investigations at the Site were used to generate the geologic cross sections. The orientations of the cross sections are shown in plan view on Figure 2-2. The cross sections are presented on Figure 2-4.

Cross section A-A' is oriented north-south, and traverses the Site from a point adjacent to the main plant entrance to the vicinity of the Slab Mill. Six lithologic units were identified in cross section A-A': weathered bedrock (saprolite); Lower Clay; Sayreville Sand; Middle Clay; Old Bridge Sand; and Trenton Gravel. The bedrock surface elevation varies from about -65 ft. MSL at boring B-131 to about -150 ft. MSL at boring DB-5. The varying bedrock surface elevation is consistent with the bedrock surface conditions described by Greenman, *et al.*, 1961.

The Lower Clay, present only in the northern portion of the section, has a thickness ranging from about 13 feet at boring DB-1 to greater than 25 feet at boring B-134. The Lower Clay is discontinuous, pinching out between these two borings at location DB-2.

The Sayreville Sand is present across the length of the section in a continuous layer of varying thickness that ranges from about 6 feet in the vicinity of boring B-154 to more than 50 feet at boring DB-5 at the southern extent of the section. The Sayreville Sand is overlain across the entire section by the Middle Clay confining unit.

The thickness of the Middle Clay ranges from about 9 feet at boring B-131 to about 50 feet at boring B-134.

The Middle Clay is continuously overlain by the Old Bridge Sand and Trenton Gravel. The two units are hydraulically connected and form the water table aquifer. The Trenton Gravel is distinguished from the Old Bridge Sand by its predominantly coarse grain size and well graded particle distribution. The thickness of the combined Old Bridge Sand/Trenton Gravel aquifer ranges from 35 to 75 feet.

Cross section B-B' is oriented east-west, crossing the northern region of the Site from Borrow Pit 20 to the vicinity of the Pipe Mill (LaClede Steel). The lithologic units present in cross section B-B' are the same as those identified in cross section A-A', however, the Lower Clay is absent from this section. The bedrock surface is generally shallower across the northern portion of the Site. In general, the depth to bedrock changes continuously from east to west across the section, increasing from about -35 ft. MSL at boring DB-11 to more than -130 ft. MSL approaching the Delaware River at boring PTP1D.

In the northwestern portion of the Site, the shallow bedrock surface is overlain by the Middle Clay, while eastward from boring DB-10, bedrock is in contact with the Sayreville Sand. The Sayreville Sand is absent from the northwestern region of the Site. Where the Sayreville Sand is present, its thickness ranges from about 5 to 40 feet. The Middle Clay forms a continuous confining layer across the section, overlying the bedrock in the west and the Sayreville Sand in the east. In the northeastern area of the Site, the Middle Clay forms the upper confining unit of the Sayreville Sand. The thickness of the Middle Clay varies across the section from 10 feet to more than 30 feet.

The Old Bridge Sand is overlain by the Trenton Gravel, and the two formations form the water table aquifer across the entire northern region of the Site. The two units are not separated by a confining layer, and their total thickness ranges from about 30 to 60 feet.

Cross section C-C' is oriented east-west, and traverses the southern portion of the Site from a point west of the Terminal Treatment Plant to the vicinity of the Wire Mill. All of the lithologic units discussed in the preceding cross sections were identified in section C-C', with the addition of the Farrington Sand. The depth to bedrock in the southern portion of the Site is consistently deeper than elsewhere on site, ranging from -120 ft. MSL at boring BK-676 to -155 ft. MSL at boring DB-8.

In the western portion of the section, the Farrington Sand overlies bedrock, and is separated from the overlying Sayreville Sand by the discontinuous Lower Clay semi-confining unit. Where present, the Farrington Sand is about 30 feet thick and the Lower Clay is about 20 feet thick. The Sayreville Sand forms a continuous layer across the southern portion of the Site. The thickness of the Sayreville Sand ranges from 10 to 50 feet across the southern portion of the Site.

The Middle Clay forms a continuous confining unit across the top of the Sayreville Sand throughout the section. The thickness of the Middle Clay ranges from approximately 25 to 55 feet.

The Old Bridge Sand/Trenton Gravel water table aquifer is considerably thicker across the southern portion of the Site than elsewhere. The thickness of the two units ranges from about 50 to 80 feet. The Old Bridge Sand is interrupted by a lens of clay 25 to 30 feet thick at borings B-156 and B-155. The clay layer is not hydraulically important due to its limited horizontal extent.

2.2.4 Subsurface Sampling

Ten of the split-spoon samples were analyzed for one or more of the following parameters: remolded porosity; particle size analysis; total organic carbon content (EPA Test Method 9060); and cation exchange capacity (EPA Test Method 9080). The sample designations, sample depths, stratigraphic units, and analytical parameters are presented in Table 2-4. The soil physical properties tests were completed by Valley Forge Laboratories in Devon, Pennsylvania; chemical analyses were completed by NYTest Environmental, Inc. in Port Washington, New York.

In addition to collecting split-spoon samples during the stratigraphic boring program, five representative thin-walled tube (Shelby tube) samples from the major confining units encountered in deep borings DB-2 and DB-8. The locations are shown on Figure 2-2. The objectives of Shelby tube sampling were to determine the vertical permeability of the confining units/weathered bedrock (saprolite), and to identify general hydraulic properties of the water-bearing units.

The five Shelby tube samples were analyzed for permeability using a triaxial flexible wall permeameter (ASTM D5084). Nine split-spoon samples were also collected and analyzed for the following parameters: remolded porosity (US Army COE); particle size analysis (ASTM D422-

63); total organic carbon content (EPA Test Method 9060); and cation exchange capacity (EPA Test Method 9080).

Additional subsurface samples, as specified in the Phase I RFI Interim Report (see "Response to Comments", June 17, 1996) and approved by EPA (July 18, 1996), were collected in August and November 1996, during installation of the Phase I groundwater monitoring network. Two Shelby tube samples were collected and analyzed for permeability (ASTM D5084), remolded porosity (US Army COE), and particle size analysis (ASTM D422).

Table 2-5 presents the test results from the subsurface samples. The analytical support documentation is provided in Appendix 2-5. The cell pressures for the flex wall permeability tests were adjusted to reflect in-situ overburden pressures. Permeability values of the various clay confining layers ranged from 2.29×10^{-8} (saprolite) to 3.53×10^{-7} cm/sec (middle clay). Permeability was also determined in several discontinuous clay lenses encountered in the shallow water table aquifer; values were 5.56×10^{-8} and 2.27×10^{-7} cm/sec.

Total organic carbon concentrations ranged from 141 mg/kg in sample DB-8 (159-161 feet) to 83,500 mg/kg in sample DB-8 (14-16 feet). Sample DB-8 (14-16 feet) was collected from a laterally discontinuous lense of Holocene Age organic clay. Average total organic carbon values for the various water-bearing units were as follows: shallow water table (21,718 mg/kg), deep water table (336 mg/kg), middle clay (1,784 mg/kg), confined aquifer (261 mg/kg), saprolite (594 mg/kg).

Cation exchange capacity ranged from 1.14 meq/100 grams in sample MW6-29-73 (50-52 feet) to 60.3 meq/100 grams in sample MW1-23-47 (40-42 feet). Both of these samples were collected in the deep water table aquifer. Average cation exchange capacity values for the various hydrostratigraphic units were as follows: shallow water table (3.27 meq/100 grams), deep water table (22.8 meq/100 grams), middle clay (27.3 meq/100 grams), confined aquifer (7.31 meq/100 grams), saprolite (27.3 meq/100 grams).

Remolded porosity values ranged from 26 percent in the shallow water table aquifer to 43 percent in the deep water table aquifer. Average remolded porosity values for the various units were as follows: shallow water table (30.3 percent), deep water table (39.0 percent), middle clay (34.8 percent), confined aquifer (33.3 percent), saprolite (34 percent).

Samples collected from the four water-bearing units were described according to the USCS, based on particle size distribution results. The particle size distribution curves of three samples of Trenton Gravel, three samples of Old Bridge Sand, one sample of Sayreville Sand, and two samples of Farrington Sand were evaluated (see Appendix 2-5). A description of each unit is provided below:

- Trenton Gravel - (GP) Dark-brown sand (30-50 percent) and gravel (50-70 percent) with approximately 3 percent silt or clay. Sample DB-8 (29-31 feet) was also collected from the Trenton Gravel and consisted of a dark-brown, poorly graded, fine to medium sand with trace (5 percent) gravel.

- Old Bridge Sand - (SP) Brown to orange-brown, poorly graded, fine sand with little clay (10 to 20 percent) and trace gravel (<10 percent).

- Sayreville Sand - (SW) Orange to light-brown, well graded sand with trace clay (about 10 percent) and gravel (<10 percent).

- Farrington Sand - (SW) Gray-brown, generally well graded, fine and medium sand with little clay (15 percent) and trace fine gravel (1-5 percent).

2.3 HYDROGEOLOGY

A substantial investigation of the hydrogeology of Fairless Works was conducted as part of the Phase I RFI. The investigation generally consisted of a survey to determine the condition of existing monitoring wells, a well location/elevation survey, a 72-hour tidal monitoring program, water level measurements collected from the existing monitoring wells, and slug tests to determine hydraulic conductivity. The objectives of the investigation were as follows:

- Obtain site-wide hydraulic head data in the aquifers at the Site

- Determine the influence of Delaware River tidal fluctuations on the water table and confined aquifers

- Provide data for the groundwater flow model

2.3.1 Existing Monitoring Wells

Previous studies at Fairless Works were reviewed, and it was determined that 150 groundwater monitoring wells had been installed during various groundwater investigations. Well construction specifications and lithologic logs were obtained and entered into a monitoring well data base. The wells were located in the field, visually inspected, and where possible, well construction specifications were confirmed by direct measurement. The results of the field verification survey indicated that a total of 90 monitoring wells were in suitable condition for future use.

Following verification of the status of existing wells, a new, site-wide nomenclature system was adopted, changing the prior designations. The new well nomenclature system consists of three subparts based on location, relative order of installation, and total depth (i.e., monitoring well MW6-29-73 was installed in the area included on Sheet 6 of the Site topographic survey, .the twenty-ninth monitoring well installed, and was screened to a depth of 73 feet).

The existing wells were categorized according to their use or potential future use during the RFI. Wells monitoring individual borrow pits were identified and grouped together based on location, screened interval, and aquifer. Miscellaneous wells, not associated with potential RFI concerns, were excluded. Monitoring wells that are of interest (82 wells) are listed in Table 2-6.

In order to utilize the existing monitoring wells in a network, a well location and elevation survey was completed. The wells were surveyed by Pickering, Corts, and Summerson, Inc. of Newtown, Pennsylvania, beginning in January 1995 and concluding in March 1995. All survey activities were supervised by a Pennsylvania-licensed land surveyor. The location of each well was determined to the nearest 0.01 foot, based on the NAD 1983. At each well, the elevations of the top of the outer steel casing and top of the inner polyvinyl chloride (PVC) casing (if present) were determined to the nearest 0.01 foot, with respect to the NGVD 1929. In addition, the ground surface elevation at the base of the outer protective casing was determined to the nearest 0.1 foot, with respect to the NGVD 1929.

The surveyed well locations were transferred onto an existing, topographic map of the site. The site was divided into nine areas that correspond to the nine sheets of topographic maps. The first character of the well designation identifies which sheet the well appears on and, therefore, the general location of the well. The surveyed well locations are presented on Figure 2-5.

2.3.2 Tidal Monitoring

The objectives of tidal monitoring were as follows:

- Determine the range, magnitude, and areal extent of tidal fluctuations in the water table and confined aquifers
- Calculate transmissivity and storage in the water table and confined aquifers
- Determine time-weighted mean groundwater elevations in tidally influenced wells

Calculation of mean groundwater levels was critical in determining site-wide hydraulic gradients and groundwater flow directions.

The tidal study was conducted from February 20, to February 22, 1995, for a duration of 72 hours. Water levels were measured at 22 wells and surface water gauges. Data was collected continuously at 10-minute intervals using pressure transducers and electronic data recorders. All of the monitored points were surveyed prior to initiating the tidal study. Figure 2-5 shows the surveyed locations of the wells and surface water gauges included in the tidal study. The 13 monitoring wells and their associated aquifers are listed in Table 2-7. A total of nine surface water gauges were monitored during the study: three points on the Delaware River, designated SW-1 to SW-3; three points on the on site canals, designated SG-1 to SG-3; one point on Biles Creek, designated SG-4; one point on Scott's Creek (Manor Lake), designated SG-5; and one point on Van Sciver Lake, designated SG-6 (Table 2-7). Barometric pressure was also monitored during the 72-hour study, using a pressure transducer designed specifically for that purpose.

Surface water levels were monitored by combining either staff gauges or stilling wells with pressure transducers. Staff gauges were constructed by attaching graduated metal placards to permanent man-made structures extending out into the water bodies, such as boat docks and outfall pipes. The purpose of the stilling wells was to eliminate river wave action, resulting in more accurate hydraulic head measurements. However, construction of stilling wells as proposed in the Phase I RFI Work Plan proved difficult. In their place, surface water level monitoring stations were installed by attaching heavy weights to pressure transducers and submerging these devices in the river at low tide. Reference markers were surveyed on the river banks, and from these points the river elevation was surveyed before data collection started.

Stilling Well No. 1, located at the boat slip, consisted of a 10-inch diameter steel casing attached to the boat slip bulk head. The end of the casing projected into the river and was always below the water line.

Staff Gauge No. 4, located on Biles Creek, was swept away by ice and subsequently replaced by a "modified" stilling well. Equipment failure caused the loss of data from well pair FUB04 (MW5-37-29) and FUB05D (MW5-36-82). The water levels at these locations were monitored again for a 72-hour period starting on March 22, 1995.

Determining the Range and Extent of Tidal Fluctuation in the Aquifers

The first objective of the tidal study was to determine the range of tidal response in groundwater and surface water at the Site, and to identify the areal extent of the tidal influence in each aquifer. As a first step in evaluating the tidal study results, tidal fluctuation in the Delaware River were examined. Figure 2-6 depicts water level fluctuations observed in the Delaware River during the tidal study. The tidal range of the Delaware River was approximately 7.7 feet at the Site. The average time between high and low tide (tidal period) observed during the 72-hour study was 12.7 hours.

Atmospheric pressure can influence groundwater levels in confined aquifers, therefore barometric pressure measurements were continuously recorded during the tidal study. Figure 2-7 is a graph of barometric pressure and hydraulic head in the confined aquifer with respect to time. No correlation was evident between barometric pressure and hydraulic head in the confined aquifer.

Figures 2-8 to 2-20 depict hydraulic head values measured at each well that was included in the 72-hour tidal survey. The tidal fluctuations recorded at the Delaware River (SW-1) are also provided on each figure, for comparison. Table 2-8 presents a summary of the tidal study results, including distance of the monitoring point from the Delaware River, aquifer, and average range of tidal fluctuation.

The Delaware River tidal cycle is asymmetric, as indicated by the shape of the sine curve generated by graphing the Delaware River tidal study data (see Figure 2-6). The asymmetry of the tidal cycle is also apparent in the aquifer response data. In general, the average gaining tide ranges are slightly greater than the average losing tide ranges.

The tidal study results also show that the magnitude and areal extent of tidal influence is greater in the confined aquifer than in the water table aquifer. Significant tidal fluctuations (greater than 0.1 foot) in the water table aquifer were limited to within several hundred feet of the Delaware River, although minor tidal influence in the water table aquifer was observed at a distance of 6,400 feet from the Delaware River. In comparison, significant tidal fluctuations exceeding 1.0 foot were recorded in the confined aquifer several thousand feet from the river. Tidal fluctuations in the confined aquifer seem to dissipate at about 6,400 feet. Figure 2-21 depicts the tidal effects on well pair MW4-31-132 (PWD) and MW4-30-63 (PWS) located approximately 1,400 feet from the Delaware River. Well PWD is screened in the confined aquifer, PWS in the water table aquifer. No tidal response was apparent in well MW4-30-63 (PWS). Similar results were recorded in well pair MW4-15-119 (88) and MW4-14-36 (87) located about 2,300 feet from the Delaware River, as shown on Figure 2-22.

In general, the lakes and canals at the selected monitoring points were not influenced by Delaware River tides. Figure 2-23 depicts water level fluctuations observed at Van Sciver Lake and Scott's Creek (Manor Lake) during the tidal survey. No tidal fluctuations were observed at either location. The water elevations in Van Sciver Lake and Scott's Creek differ by approximately 2.5 feet. Figure 2-24 shows water level measurements recorded at the three on site canals during the tidal study. Tidal fluctuations were observed in the West Canal only. The response in the West Canal was asymmetric, because incoming water was obstructed by an earthen berm. Water rose above the elevation of the berm during high tide and rapidly filled the canal behind the berm. After the tide peaked, ponded water slowly drained back through the berm, and the water level in the canal declined.

Calculation of Aquifer Characteristics

Measurements of tidal response in an aquifer can be used to estimate the transmissivity and storage coefficients of the aquifer. A more permeable aquifer will respond more quickly and at greater distances from the tidal source than will a lower permeability formation. This relationship was used to calculate the ratio of aquifer transmissivity to storage (T/S), based on the equations presented in Ferris, 1963:

TIME LAG EQUATION $$\frac{T}{S} = \frac{x^2 t_0}{4\pi\left(t_r^2\right)}$$

x = distance of well from river (feet)
t_0 = period of tidal cycle in river (days)
t_r = period of tidal cycle in well (days)
T/S = ratio of transmissivity to storage (ft²/ day)

STAGE RATIO EQUATION $\frac{T}{S} = \frac{\pi}{t_0}\left(\frac{x}{-\ln(S_r / 2S_0)}\right)^2$

S_r = half range of tide in well (feet)
S_0 = half range of tide in river (feet)
x = distance of well from river (feet)
t_0 = period of tidal cycle in river (days)
T/S = ratio of transmissivity to storage (ft^2/day)

The T/S ratio was calculated from the tidal study data collected at six wells; three wells were screened in the water table aquifer, and three wells were screened in the confined aquifer. The T/S ratio was estimated using both the TIME LAG and STAGE RATIO equations presented above. The calculations are provided in Appendix 2-6. The results are summarized in Table 2-9.

The calculated average T/S values were used to estimate the time-weighted mean groundwater elevations in 72 wells located throughout the site.

2.3.3 Calculation of Time-Weighted Mean Groundwater Levels

One round of groundwater level measurements was collected from the existing groundwater monitoring network. The purpose of collecting the groundwater elevation data was to generate water table and potentiometric contour maps for the aquifers beneath the Site, and to provide data for use during calibration of the groundwater flow model. However, measured water levels in tidally influenced wells cannot be used directly to identify hydraulic gradients and groundwater flow directions. The water levels in these wells are fluctuating at different frequencies (time lags) and amplitudes (stage ratios) as a function of the tidal stage, distance of the well from the tidal source, and aquifer properties (T/S ratio). Calibrating a steady-state groundwater flow model to a set of unmodified water levels collected in a tidally influenced aquifer would be inappropriate.

In order to address this condition, the 72-hour tidal survey results and the TIME LAG and STAGE RATIO equations (Ferris, 1963) were used to calculate the time-weighted mean groundwater elevations in 72 monitoring wells located throughout the Site.

The first step in calculating time-weighted mean groundwater elevations was to collect groundwater elevation data from the existing monitoring well network. The depth to groundwater was measured at 72 wells on March 10, 1995. The measurement points are listed in Table 2-10 and shown on Figure 2-5. All measurements were collected within a 5-hour period, and were made to the nearest 0.01 foot interval using an electronic depth to water probe. Each reading included the reference point on the well casing from which the groundwater depth was measured. The time of each measurement was also recorded to allow correlation of the data to the tidal cycle in the Delaware River. The depth to groundwater measurements were converted to elevations with respect to mean sea level, using the well elevation survey data.

As discussed previously, the TIME LAG and STAGE RATIO equations were used to determine the T/S ratios of the water table and confined aquifers. By rearranging the TIME LAG equation as shown below, the time at which the maximum or minimum groundwater stage occurred in a given monitoring well can be determined if the aquifer properties and tidal cycle in the river are known. Similarly, the STAGE RATIO equation can be used to calculate the range of tidal groundwater fluctuation in a well. The two equations are as follows:

TIME LAG EQUATION $$t_r = \sqrt{\frac{x^2 t_0}{4\pi} \frac{S}{T}}$$

x = distance of well from river (feet)
t_0 = period of tidal cycle in river (days)
t_r = period of tidal cycle in well (days)
S/T = calculated ratio of storage to transmissivity (day/ft^2)

STAGE RATIO EQUATION $$S_r = 2S_0 \exp\left(-x\sqrt{\frac{\pi}{t_0} \frac{S}{T}}\right)$$

S_r = half range of tide in well (feet)
S_0 = half range of tide in river (feet)
x = distance of well from river (feet)
t_0 = period of tidal cycle in river (days)
S/T = ratio of storage to transmissivity (day/ft^2)

The period of a tidal cycle is the time from high to high or low to low tide. The tidal half range is equal to one-half the height of the tidal sine wave. The time lag and stage ratio at each well was determined using these two equations, and given the following input parameters:

- Elevation of groundwater in well (feet)
- Time of groundwater elevation measurement taken in well (days)
- Distance of well from river (feet)
- T/S ratio of appropriate aquifer (ft^2/day)
- Period of tidal cycle in Delaware River (days)
- Half range of tide in Delaware River (feet)

Calculated time lag and stage ratio values to actual values were compared of these parameters obtained during the tidal study. The objective was to determine the correlation between observed and predicted tidal fluctuations in selected wells. The correlation was quantified by calculating the relative percent difference (RPD) between the actual and predicted values. In general, the correlation between calculated and actual time lag and stage ratio results varied among the wells because an average T/S value was used to calculate time lag and stage ratio values throughout the site. At some well locations, the average T/S value did not accurately represent local aquifer permeability. Calculation of RPD for a water table well (MW4-10-23) and a confined well (MW4-31-132) is shown in Table 2-11.

After the time lag and stage ratio values were calculated at each well, the data was evaluated to identify those wells that were not significantly influenced by the tide in the Delaware River. If the calculated full range of the tidal cycle in a well (R_C) was less than 0.10 foot, the tidal influence in the well was considered insignificant, and the measured groundwater elevation was used directly without modification. Many of the wells screened in the water table aquifer were not significantly affected by the tide, due to their distance from the river.

If a significant tidal influence was identified in a well, the time-weighted mean groundwater elevation was determined by a series of simple calculations. First, the calculated time of high tide in the well (T_H), the calculated time of low tide in the well (T_L), and the actual time the groundwater elevation was measured (T_M) were compared to determine if the groundwater elevation measurement was collected within a high to low tide cycle or within a low to high tide cycle. If, for example, T_M falls within a low to high tide cycle in the well, the relative position of T_M in the tidal cycle can be calculated as a percent using the following equations:

- $\%T_H = (T_H - T_M) / (T_H - T_L)$
- $\%T_L = (T_M - T_L) / (T_H - T_L)$

Given the calculated total range of the tidal cycle in the well (R_C) and the measured head in the well (H_M) at time T_M, the head in the well at high tide (H_H) and the head in the well at low tide (H_L) were determined using the following equations:

- $H_H = H_M + (R_C * \%T_H)$
- $H_L = H_M - (R_C * \%T_L)$

Finally, the time-weighted mean head value in the well (H_{ave}) was determined as follows:

- $(H_{ave}) = [H_H - H_L / 2] + H_L$

Table 2-10 presents the time-weighted mean groundwater elevations calculated from hydraulic head values measured on March 10, 1995. The calculated tidal range (R_C) was greater than 0.1 foot in 20 wells: 9 wells screened in the water table aquifer and 11 wells screened in the confined aquifer. The tidal response was considered significant in these wells; therefore, time-weighted mean groundwater elevations were calculated. For wells with insignificant tidal influence, the measured head values (H_M) were used directly.

The modified March 10, 1995 groundwater elevations were used to construct groundwater contour maps, interpret hydraulic gradients, and calibrate the groundwater flow model. The groundwater contour map is shown as Figure 2-25. In contouring this data, some locations were more heavily weighted than others, because of inherent inaccuracies in the calculation and adjustment for tidal affects.

A subsequent set of groundwater table measurements was obtained for the purpose of verifying the groundwater flow model on September 4, 1996, and is shown in Table 2-12. The average head was calculated for wells subject to tidal fluctuation, in the same manner described above. Figure 2-26 depicts the tidal range in the Delaware River for that period. The groundwater contour map for the water table aquifer, based on September 4, 1996 water levels, is shown as Figure 2-27. The groundwater contours are an average of about 2 feet higher than the March 10, 1995 levels (due to the abnormally high precipitation during the summer of 1996), but the general flow pattern is very similar.

2.3.4 Aquifer Slug Testing

To aid in calibration of the groundwater model, aquifer slug tests were performed in two wells screened in the confined aquifer, MW1-22-173 and MW4-15-119 (formerly well 88). The purpose of the slug tests was to determine a reasonable range of permeability values for the confined aquifer.

Slug tests were performed at the two well locations on June 9, 1995. For the slug test method, the hydraulic head in a monitoring well is suddenly changed by the immersion or withdrawal of a cylinder of known volume (slug) into or out of the well. The rate of hydraulic head recovery to equilibrium was measured with a pressure transducer and electronic recording device. These data were evaluated using the Cooper, Bredehoeft, and Papadopulos method for estimating hydraulic conductivity in a confined aquifer (Cooper, *et al.*, 1967).

The data obtained during the slug tests are presented in Appendix 2-7, along with graphs showing changes in hydraulic head and type-curve matches. The calculated aquifer characteristics are shown in Table 2-13.

Parameters were not determined for well MW1-22-173. When the slug was placed in this well, the hydraulic head increased correspondingly. However, the water level did not respond by decreasing as water flowed back into the formation. Instead, the water level stabilized at the higher level. Because of this odd response, the test was attempted a second time with the same results. The results of the slug test show that this well is poorly connected to the sand unit in which it is screened. A possible reason for this poor connection is that the well may need additional development. The borehole was drilled using mud rotary techniques which introduce clays into the formation.

On February 4, 1997, additional slug tests were completed in the following wells:

- MW6-20-37, MW4-37-29, MW1-27-19 (shallow water table aquifer wells)
- MW6-29-73, MW2-4-77, MW1-28-74 (deep water table aquifer wells)
- MW7-14-75 (confined aquifer well)

The method of Bouwer and Rice (1976) was used to calculate the hydraulic conductivity in the water table zones. Test data obtained from well MW7-14-75 was evaluated using the Cooper, Bredehoeft, and Papadopulos method for estimating hydraulic conductivity in a confined aquifer (Cooper, *et al.*, 1967).

Slug test results are provided in Table 2-14. Raw data and calculations are included in Appendix 2-8. Average hydraulic conductivities for the shallow water table aquifer ranged from 2.4 to 76.8 ft/day, with an average value of 35.8 ft/day. Average hydraulic conductivities for the deep water table aquifer ranged from 48.8 to 93.2 ft/day, with an average value of 49.9 ft/day. The hydraulic conductivity in the confined aquifer was 49.3 ft/day.

2.4 OPEN WATER HABITATS

There are substantial areas of aquatic and semi-aquatic habitat located in the on site open waters and on site canals which are SWMUs or AOCs. Potential impacts to these habitats were evaluated as part of the Phase I RFI activities, and the results of this evaluation are described in Section 6.2.1. Because these habitats are associated with SWMUs/AOCs, they are the most likely of such habitat locations to have potentially been impacted by contamination at the site.

Historical aerial photography, prior to 1952, indicates that nearly the entire property was used for agricultural purposes. During construction of Fairless Works, borrow pits were excavated to provide fill material and raise the elevation of production facilities above the floodplain. Many of these borrow pits were partially or completely backfilled with slag and other material.

The on site open waters habitats have developed naturally, in borrow pits that were left open or partially backfilled. The developing habitats in these on site open waters reflect the conditions present in the borrow pits.

Similarly, the canals were created by U.S. Steel to convey process water, non-contact cooling water, and stormwater to the Delaware River. Aquatic and semi-aquatic habitats have developed naturally, in and along the canals. These habitats reflects the physical and potentially the chemical conditions present.

The evaluation of on site open waters and canal habitats in the Phase I RFI is aimed at determining, through the evaluation of a sensitive biological community (anurans) in on site open waters and benthic communities in the canals, whether there are impacts from contamination. Section 6.2 presents the results of these evaluations.

2.5 SURFACE WATER

Surface water bodies adjacent to or within Fairless Works include the Delaware River and Biles Creek (which is a small channel of the Delaware River that separates Biles Island from the facility); Van Sciver Lake, located 0.5 miles west of the facility; and the on site open waters and canals describes above and evaluated in Sections 6.2.1 and 6.2.2.

The Delaware River is discussed and evaluated in detail in Section 6.2.3. Data concerning tidal fluctuations in the Delaware River was presented in Section 2.3.2, Tidal Monitoring. Water levels in Van Sciver Lake were surveyed as part of the groundwater modeling effort, and clearly confirm that Van Sciver Lake is upgradient from the facility and not a concern (except potentially as an upgradient background groundwater source).

The evaluation of surface water focused on the potential for Fairless Works to impact the Delaware River. Section 5.0 describes the flow of groundwater from the water table aquifer to the Delaware River, and Section 6.0 describes the analytical results from the groundwater monitoring well network used to assess groundwater flow to the river. The results of groundwater sampling and analysis are described in Section 6.0, including a comparison to aquatic water quality standards for the Delaware River.

Existing data on the Delaware River is reviewed and evaluated in Section 6.2.3. Because the river is a large and hydrologically complex (Fairless Works is located at the head end of a tidal estuary with a tide range of about 7 feet and an average flow rate of 12,000 CFS), and has a long history of anthropagenic impacts, the relationship between Fairless Works and the Delaware River is not readily observable. However, the information presented in Section 6.2.3 indicates that Fairless Works has not adversely impacted the Delaware River.

2.6 CLIMATE

The climate of the southeastern Coastal Plain and Piedmont Plateau in Pennsylvania is relatively moderate, with long and at times uncomfortably hot summers, and mild winters. Daily temperatures reach 90° F or above an average of 25 days during the summer season; however, readings at 100° F or above are comparatively rare.

From the beginning of July to the middle of September, this area occasionally experiences uncomfortably warm periods, four to seven days in length, during which light wind movement and high relative humidity make conditions oppressive. The prevailing wind direction during the summer months is from the southwest. The July mean temperature is 88° F and the mean minimum temperature for the same month is 66° F.

The winters are, in general, comparatively mild, with an average of less than 100 days with minimum temperatures below the freezing point. Temperatures of 0° F or lower occur in the Philadelphia area an average of one winter in four. The freeze-free season averages 187 to 200 days. The mean maximum temperature for January is approximately 40 to 42° F, and the mean minimum temperature is 24 to 26° F.

Average annual precipitation in the area ranges from about 30 inches in the lower Susquehanna Valley to about 46 inches in Chester County. Under the influence of an occasional severe coastal storm, a normal month's rainfall may occur within a period of 48 hours. The average seasonal snowfall is about 30 inches, and fields are ordinarily snow covered about one third of the time during the winter season. The mean annual precipitation for the local area is 44 inches to 46 inches.

Mean monthly temperature and mean monthly precipitation records from the NOAA weather station at Neshaminy Falls, Pennsylvania are shown in Table 2-15. The most important factor governing the regional climate is the moderating and moistening effect of the nearby Atlantic Ocean. However, the climate is also effected to a lesser extent by the eastward movement of storms across the continent, by cold air masses from the north, and by warm air masses from the south. (Kimball, 1976)

A wind rose generated from the National Weather Service's joint frequency distribution of meteorological surface conditions at the Philadelphia, Pennsylvania reporting station for the calendar year 1992 is shown on Figure 2-28. The prevailing wind direction for the summer months is from the southwest, while northwesterly winds prevail in the winter. The annual prevailing direction is from the west-southwest. Destructive velocities are comparatively rare, and occur mostly in gusts during summer thunderstorms. High winds occurring in the winter months, as a rule, come with the advance of cold air after the passage of a deep low pressure system. Only rarely have hurricanes in the vicinity caused widespread damage (most damage results from storm flooding).

3.0 SWMUS AND AOCS

3.1 DESIGNATED SOLID WASTE MANAGEMENT UNITS (SWMUS)

As described in the Description of Current Conditions, 48 areas where wastes have been stored, processed, landfilled, or impounded at Fairless Works were identified as Solid Waste Management Units (SWMUs) in the Draft Phase I RFA Report prepared for the EPA by Environmental Science and Engineering, Inc. These SWMUs (shown on Figure 3-1) include borrow pits that were used as a source of fill for construction purposes at Fairless Works, and industrial wastewater treatment facilities, including the Finishing Mill Treatment Plant (FMTP), the Terminal Treatment Plant (TTP), and the Rod Mill Settling Lagoon.

3.1.1 Borrow Pits

Borrow pits that received waste materials are listed in Table 3-1, along with the types of materials placed in each of the borrow pits, the approximate surface area of the pits, the estimated quantity of material placed in the pits, and the current status of the pits.

3.1.2 Industrial Wastewater Treatment Facilities

Three facilities where process water is treated on site were identified as SWMUs in the Draft Phase I RFA Report. The FMTP is used to treat process water from the Sheet Mill, the Tin Mill, and tenant operations). Effluent from the FMTP receives further treatment at the TTP, which provides treatment of process water from additional tenant operations, and surface water removed from BP-35, as well. Effluent from the TTP is discharged to the Delaware River, under the facility's NPDES Permit.

The Rod Mill Settling Lagoon was used for the treatment of process water from the Rod Mill and Wire Mill, from 1969 to 1984. Effluent was discharged to the Central Canal, under the facility's NPDES Permit. As noted in Section 1.1 of this report, interim measures have been implemented at the Vac All basin, adjacent to the Rod Mill Settling Lagoon.

3.2 OTHER SWMUS AND AREAS OF CONCERN (AOCS)

3.2.1 Refuse Disposal Area

The refuse disposal area is located east of BP-35, on a site covering approximately 14 acres. Prior to use for disposal, the area consisted of level ground with sparse vegetation. This area was active from 1952 until 1985, and was used for the disposal of general plant refuse or debris. These materials included waste paper, wooden pallets, broken furnace lining materials, refractory brick, waste building materials, ore fines, and rubble.

3.2.2 Former USTs

Wherever possible, U.S. Steel has removed underground storage tanks (USTs) that were not essential for operating purposes, closed others in place that could not be removed, and installed leak detection equipment on the remaining USTs.

Seven 3,000 to 4,000 gallon underground storage tanks (USTs) containing gasoline and diesel fuel were removed from the former American Bridge yard, at the north end of Fairless Works. The tanks, visibly contaminated soil, and free product were removed from the excavations and disposed of; groundwater monitoring wells were installed at upgradient and downgradient locations.

Two 15,000 gallon diesel fuel tanks were removed from the open hearth locomotive fueling station, in 1990 and 1992. The tanks, visibly contaminated soil, and free product were removed from the excavations and disposed of; groundwater monitoring wells were installed at upgradient and downgradient locations.

A 20,000 gallon no. 6 fuel oil tank in a concrete vault below the powerhouse was cleaned and closed in place, because removal was structurally impracticable. Although tightness testing showed that the tank was not leaking, borings and monitoring wells were installed around the powerhouse building to investigate fuel oil which may have leaked from a fuel line associated with the tank.

4.0 SLAG EVALUATION

4.1 INTRODUCTION

Iron and steel slags are essential by-products in the making of iron and steel. They have long been classified as mineral commodities by the U.S. Department of the Interior (DOI), which publishes an annual report on the iron and steel slag industry. The 1991 DOI annual report provided the following concise descriptions of iron and steel slags:

> Iron and steel slags are byproducts of the iron and steel industry and are used in numerous commercial applications in construction and roadbuilding . . .
>
> In the production of iron, the blast furnace is charged with iron ore, flux stone (limestone and/or dolomite), and coke for fuel. Two products are obtained from the furnace: molten iron and slag. The slag consists primarily of the silica and alumina from the original iron ore combined with calcium and magnesium oxides from the flux stone . . .
>
> The steel industry also produces steel slag during the steelmaking process. The manufacture of steel involves the removal from the iron of excess quantities of carbon and silicon by oxidation. Steel slag is composed of roughly 50% lime. The other two main constituents are silica and iron oxide.

The DOI's 1991 annual report also noted that the EPA had determined, in 1991, that iron and steel slags are not subject to regulation as hazardous wastes:

> In 1991, the Federal Environmental Protection Agency (EPA) concluded that regulation of iron and steel slags as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) was inappropriate. This decision presented the final regulatory determination that iron and steel slags were not subject to Federal regulation as hazardous wastes.

Since that time, the DOI (and the iron and steel slag industry, in general) have come to explicitly recognize that slag is a coproduct, rather than a by-product, of iron and steel production. In contrast to the above description of slag in the DOI's 1991 annual report, the 1995 annual report on iron and steel slags still described these materials as by-products, but noted that they are, in fact, coproducts:

> Iron (or blast furnace) and steel slags are silicate byproducts or iron- and steelmaking . . .
>
> Slag is properly recognized as a valuable coproduct of iron- and steelmaking, not a waste product.

By the time that the DOI's 1996 annual report was published, iron and steel slags were no longer referred to as by-products at all: "The diverse uses of iron and steel slags, coproducts of the iron and steel industry, range from construction and road building to waste stabilization." In its 1997 Mineral Commodities Summary for Iron and Steel Slag, the DOI described these slags in the following manner: "No longer regarded as waste or minimally useful byproducts of iron- and steelmaking, ferrous slags today are viewed as valuable coproducts of ferrous smelting and are among the most valuable of recycled materials."

Distinguishing between the classification of iron and steel slags as either by-products or coproducts is not without significance. In 1992, the Pennsylvania Department of Environmental Protection (PA DEP) adopted regulations relating to the management of residual wastes, and included in those regulations the following definitions:

> *By-product* - A material generated by a manufacturing or production process that is not a product or coproduct, regardless of whether it has value to the generator or another person.
>
> *Coproduct* -
>
> (i) A material generated by a manufacturing or production process, or an expended material, of a physical character and chemical composition that is consistently equivalent to, or exceeds, the physical character and chemical composition of an intentionally manufactured product or produced raw material, if the use of the material presents no greater threat of harm to human health and the environment than the use of the product or raw material.
>
> (ii) The term only applies to one of the following:
>
> (A) If the material is to be transferred in good faith as a commodity in trade, for use in lieu of an intentionally manufactured product or produced raw material, without processing that would not be required of the product or raw material, and the material is actually used on a regular basis.
>
> (B) If the material is to be used by the manufacturer or producer of the material in lieu of an intentionally manufactured product or produced raw material, without processing that would not be required of the product or raw material, and the material is actually used on a regular basis.
>
> (iii) A waste may become a coproduct after processing if it would otherwise qualify as a coproduct.
>
> (iv) A person producing, selling, transferring, possessing or using a material as a coproduct has the burden of proving, by a preponderance of evidence, that the material is a coproduct, and not a waste.

Iron and steel slags have historically been used for the same purposes as other similar mineral commodities, and thus should be (and are) quite properly classified as coproducts. The PA DEP's "Coproduct (CO) and Dewaste (DE) List" as of July 23, 1997 (included in Appendix 4-1) lists more than a dozen instances in which the DEP has formally concurred with producers' or processors' designations of iron and/or steel slags as coproducts, for such diverse uses as material for leveling a parking lot, fill material for construction of a museum, railroad ballast, aggregate for engineered construction fill, underground storage tank backfill, granular fill, and road base.

By definition, the PA DEP must have determined that these uses of iron and steel slags "presents no greater threat of harm to human health and the environment" than would the use of the intentionally manufactured product or produced raw material that would have been used if not for the availability of the slag coproduct. Most of the slag from iron and steel production at Fairless Works was used commercially or sold by the contractors that processed the slag. Some of it was recycled in the iron and/or steel making processes, and some of it was used by U.S. Steel at Fairless Works, to backfill or finish grade borrow pits, or to construct roads and dikes. These uses are no different than the uses now formally accepted and endorsed by the PA DEP as presenting no greater threat to human health or the environment than would the use of clean material produced in quarries or excavated from borrow pits.

As noted by the DOI in its 1995 annual report on the iron and steel slag industry, "The utilization of slag, therefore, is one of the great, yet relatively unsung, stories of recycling." Despite the evident lack of any cause for concern over the uses to which slag was put at Fairless Works, such concerns have been voiced in the past. As part of the Phase I RFI, an evaluation was thus made to identify the general chemical composition of iron and steel slags placed in fill areas at Fairless Works, and to determine the potential for iron and steel slags to adversely impact human health or the environment.

Four tasks were undertaken to evaluate the iron- and steel-making slag present on the site:

1. Review available literature concerning the properties, generation, use, disposal, regulation, and environmental impact of slag

2. Collect and analyze representative iron- and steel-making slag samples at the Site

3. Collect and analyze groundwater samples from wells monitoring iron- and steel-making slag fill areas at the Site

4. Evaluate the potential for on site iron- and steel-making slag to impact human health or the environment

4.2 LITERATURE REVIEW

Material commonly referred to as "slag" is produced by several mining and mineral production industries; however, this review focused on slags generated as a by-product of iron and steel production. Approximately 20 documents were reviewed describing iron and steel slags at

Fairless Works and other iron- and steel-making facilities throughout the country. The documents consisted of steel company reports, technical and trade journal articles, site investigation reports, and EPA regulations and reports. A list of references is provided.

4.2.1 Description and Characteristics of Iron and Steel Slags

Iron and steel Slags are formed during the making of iron and steel by fusion of a fluxing agent with impurities in molten iron ore and iron. Both iron and steel making slags were produced at Fairless Works. Iron-making slag is produced during the reduction of iron ore to molten iron. During the iron-making process, limestone or dolomite flux is added to the furnace. The flux fuses with impurities in the iron ore to form slag. The molten slag is removed from the furnace, and cooled by several methods to a solid slag. Three types of solidified iron slag are produced, depending on the method of cooling: air-cooled slag, expanded slag, and granulated slag.

Steel-making slags are produced during the refining of molten iron or iron and ferrous scrap to steel. Fluxing materials are added to the furnace that fuse with and remove impurities from the molten steel and form steel slag. The molten steel slag is drawn off and air cooled.

Iron and steel slags are generally either used as fill or processed and sold for various commercial purposes. Iron slag has been used as structural fill or other construction material since the turn of the century, and it is listed by the U.S. Bureau of Mines as an economic mineral product. In fact, almost 100 percent of the iron slag produced in North America and Europe is processed and used in various applications (Matyas, 1978). At some facilities, old iron slag pits have been mined, and the slag processed and sold (National Slag Association, 1991). Uses for iron slag include road base, railroad ballast, concrete aggregate, water filtration media, and roofing material. At a West Virginia fish hatchery, air-cooled iron slag was chosen as water filtration media instead of limestone or shale, due to its porosity and alkalinity. These characteristics promoted retention of essential nitrogen-fixing microorganisms that removed toxic ammonia, and allowed recycling of the limited water supply (National Slag Association, 1991). Commercial applications of steel slag are limited, by comparison; only about one-quarter of steel slag production is processed and sold for use, in such applications as anti-skid asphalt mixtures, engineered fill material, and railroad ballast. Uses for steel slag are limited due to its composition.

The chemistry and physical properties of steel slag differ significantly from iron slag. Steel slag has a higher specific gravity than iron slag, due to its higher iron and manganese oxide content and lower silica and alumina content. In addition, steel slag has cementitious properties that are absent from iron slag. The cementitious properties of steel slag are of primary importance, both commercially and environmentally. Steel slag is similar in composition to Portland cement, because it contains 2 to 4 percent free lime [CaO] and magnesia [MgO] (Matyas, 1978). When hydrated, the free lime forms hydroxide compounds that cause cementation and significant, rapid, volume expansion. The expansive nature of steel slag limits its use in confined applications, especially in structural concrete. However, this commercial liability is an environmental benefit, because the cementitious reaction serves to immobilize constituents in the slag.

The mineralogy of iron and steel slag also prevents the release of constituents into the environment. Oxides of calcium, silicon, aluminum, and magnesium constitute 95 percent of iron and steel slags, with the remaining 5 percent consisting of sulfides, iron oxides, manganese oxides, and other trace metals (National Slag Association, 1991). Table 4-1 presents the constituents identified in two samples of iron-making slag collected at Fairless Works. The major oxides combine to form silicate and alumino-silicate minerals during cooling and solidification of molten slag.

Analytical data from industry and EPA sources indicate that the total concentration of metals in ferrous slags can exceed several thousand parts per million. However, the concentration of these constituents detected in corresponding extracts from both iron and steel slags are well below regulatory levels, and typically below detectable limits. The low-leaching characteristic of ferrous slags is due to crystalline calcium silicate and calcium alumino silicate matrices that form during cooling of slag from an initial temperature of about 2,700 degrees Fahrenheit. The crystal matrices bind the elemental constituents (metal oxides and sulfur), such that metals in siliceous slag are not present in soluble forms.

4.2.2 EPA Regulations and Risk Assessment

In June 1991, a final rule was promulgated by the EPA that permanently excluded iron and steel slag from regulation as hazardous wastes under RCRA Subtitle C [40 CFR 261.4 (b) (7) (xiii) and (xviii)]. The following discussion summarizes the EPA decision-making process that lead to this regulatory exemption.

The EPA presented a detailed investigation of slags generated by the ferrous metals industry in the Report to Congress on Special Wastes from Mineral Processing (Report to Congress), dated July 1990. The EPA Report to Congress was required as part of the 1980 Mining Waste Exclusion provision of RCRA. In the Report, the EPA evaluated the hazards to human health and the environment associated with 20 "special mineral processing wastes," which it defined as "high-volume" and "low-hazard" waste. Included by the EPA as special wastes were iron slag and steel slag. The EPA evaluation of risk from ferrous metals slags used the following five-step process:

1. Identify manufacturing facilities, processes, characteristics, quantities, and management practices

2. Identify chemical composition

3. Determine the constituents of environmental concern

4. Evaluate the site-specific risk to human health and the environment

5. Review documented cases of environmental damage

The objective of the EPA evaluation of iron and steel slag was to determine if ferrous slags were "high-volume" and "low-hazard" and, therefore, warranted permanent exclusion from regulation as hazardous waste under RCRA Subtitle C. The results of each assessment step are summarized in the following paragraphs.

Generation and Characteristics

The Report to Congress identified 28 facilities, located in 10 states, that actively generated ferrous metals special wastes as of September 1989 (Fairless Works was listed as a generator of iron and steel slags). In 1988, approximately 19 million metric tons of iron slag were produced nationwide with a per-facility average of 724,000 metric tons per year. In the same year, about 13 million metric tons of steel slag were generated, yielding a per-facility average of 553,000 metric tons per year. The report indicated that the management practice for ferrous slags is processing and sale, although some facilities disposed of or stockpiled steel slag.

The EPA evaluated existing data and analyzed iron and steel slag samples from a representative number of facilities for ignitability, corrosivity, reactivity, and extraction procedure toxicity (EP Toxicity). The results indicated that ferrous metals slags do not exhibit any of the characteristics of hazardous waste. Based on these results, the EPA stated in the Report to Congress that iron and steel slags would not be subject to regulation as hazardous waste, even without the Mining Waste Exclusion provision of RCRA.

Constituents of Potential Environmental Concern

Using samples and data collected from representative facilities, the EPA analyzed total and leachate extract samples of ferrous slags. These results were compared to very conservative screening levels for human health, aquatic ecosystems, and water resources. The results of the comparison were used as a conservative tool to identify chemical constituents in slag that may cause risk. The EPA emphasized that exceedance of the three screening criteria was not an indication that slag was actually causing risk, but that slag could potentially pose a hazard to human health and the environment under conservative release and exposure scenarios.

Evaluation of total constituents in iron slag indicated that only chromium exceeded the conservative inhalation screening criterion (by a small amount). However, large slag particle sizes significantly lowered the inhalation exposure potential. Of the total constituents identified in steel slag, levels of chromium, thallium, and arsenic exceeded the conservative ingestion screening criterion, while levels of chromium, manganese, arsenic, and nickel exceeded the conservative inhalation screening criterion. Again, the EPA concluded that large slag particle sizes lowered the ingestion and inhalation exposure potentials.

The EPA also assessed ferrous slag leaching potential using a conservative leaching test procedure and using conservative human health (drinking water), aquatic ecosystem, and water resources screening criteria. The EPA conservatively assumed that minimal dilution of the ferrous slag leachate would occur during migration from the point of release to the point of long-term exposure. Evaluation of the potential hazards from iron slag leachate constituents indicated that when dilution was less than 10-fold, arsenic, lead, and antimony exceeded the conservative drinking water screening criterion. Lead, aluminum, silver, mercury, and alkalinity in iron slag leachate exceeded the conservative aquatic ecosystem screening criterion without a 100-fold dilution in surface water. Manganese, iron, lead, and alkalinity levels in iron slag leachate could potentially restrict future use of impacted groundwater and surface water bodies if dilution was 10-fold or less. None of the concentrations detected in the iron slag leachate samples exceeded EP Toxicity levels.

The same evaluation of steel slag leachate constituents indicated that fluoride, arsenic, lead, and barium levels exceeded the conservative drinking water screening criterion if the leachate dilution was less than 10-fold. Lead, silver, and alkalinity levels identified in steel slag leachate exceeded the conservative aquatic organism screening criterion if dilution was less than 100-fold, and levels of manganese, fluoride, arsenic, lead, iron, molybdenum, barium, and alkalinity in steel slag leachate could potentially restrict future use of impacted groundwater and surface water resources if the leachate was not diluted by at least a factor of ten. As was the case for iron slag, none of the compounds detected in the steel slag leachate exceeded EP Toxicity levels.

EPA's evaluation of potential risk, including analysis of slag compounds in total and leachate samples, identified only seven constituents at concentrations greater than 10 times their conservative EPA screening criteria. In iron slag, these compounds were manganese, iron, silver, lead, and arsenic; in steel slag, the compounds were manganese, chromium, iron, thallium, and arsenic. Highly alkaline pH levels were observed in leachate from both iron and steel slags. Based on these results, the EPA concluded that even under very conservative, hypothetical exposure conditions, there was only a low potential for iron and steel slags to pose risks to human health and the environment.

Site-Specific Risks to Human Health and the Environment

The EPA evaluated each generating facility's slag management practices, environmental setting, and local water resource uses. Based on survey data obtained from the mineral processing industry, the EPA concluded that the most common and representative on site slag management methods were stockpiles and slag pits. After evaluating the above-referenced criteria, the EPA rated the potential for release and migration of mobile slag constituents to groundwater, surface water, air, and sensitive environments (wetlands) at specific facilities. Similarly, it rated the potential for exposure of long-term receptors. A summary of EPA findings is presented below.

Using a leaching procedure which is conservative when compared to field conditions, the EPA concluded that arsenic and mercury are the primary mobile constituents which could be released from iron slag to groundwater. Mobile steel slag compounds which could be released to groundwater were fluoride, arsenic and molybdenum. Both iron and steel slag may potentially increase the pH of groundwater. EPA concluded that the potential for release and migration of ferrous slag constituents in groundwater at the 11 study facilities ranged from low to high.

However, they further concluded there was a low potential for significant exposure to released slag contaminants in groundwater.

The groundwater release potential at Fairless Works was considered moderate by the EPA, because on site borrow pits containing slag do not have groundwater release controls. The EPA assessment did not consider the site-wide confining units at Fairless Works, the direction of groundwater flow, or groundwater quality data. Even without evaluating these site-specific characteristics, the EPA concluded that groundwater releases of slag constituents at Fairless Works would be below levels of concern for potential receptors.

EPA concluded that iron and steel slag constituents could hypothetically enter surface water bodies by migration in groundwater that discharges to surface water, or by direct run-off of dissolved or suspended particles. The EPA concluded that the predominantly large size of slag particles limited the potential for erosion and transport of slag.

On the basis of an evaluation of conditions at Fairless Works, the EPA concluded that the Site has a relatively high potential to release slag constituents to surface water, due to the absence of groundwater infiltration or storm water runoff controls at borrow pits containing slag. The EPA also cited the close proximity of the site to the Delaware River as a factor contributing to the high potential for surface water releases of slag constituents. However, it stated that any potential release of slag compounds at Fairless Works was unlikely to adversely affect aquatic life or degrade usage, due to the large dilution effect of the Delaware River. In fact, the perimeter monitoring well network, designed as part of the Phase I RFI, has shown that the concentrations of these constituents in groundwater leaving the Site are quite low, and will not adversely effect aquatic life or degrade usage of the Delaware River (see Section 6.1 of this report).

EPA found that the concentrations of several metals identified in iron and steel slags may exceed conservative EPA inhalation screening criterion. The metals were chromium, manganese, arsenic, and nickel. Dust particles are the principle form by which ferrous slag constituents are hypothetically released into the air and inhaled. EPA concluded that only particles less than 10 micrometers in diameter are respirable, and that the potential for airborne release of slag dust was limited, because only a very small portion of iron and steel slag was weathered or crushed into particles this size.

At the time of the study, the potential for exposure to airborne slag dusts at Fairless Works was considered moderate by the EPA. Subsequently, major portions of the site have ceased operations, and the potential for dust generation is significantly reduced. The agency cited the following as negative factors: large surface areas, absence of dust suppression systems, lack of vegetation or other means of cover, magnitude of prevailing winds, and close proximity of nearby populations down wind of the Site. These factors were counter-balanced by the low tendency of slag to generate respirable-sized dust particles, and the high on site precipitation rate keeping the slag wet and suppressing dust. Furthermore, surface cover conditions at Fairless Works have improved significantly since the EPA study was complete, substantially mitigating the potential for erosion of slag particles: there is no longer any off-road traffic, which is now almost entirely on paved roads; and the large equipment that formerly operated on the Site when it was an active iron and steel producing facility, much of it on slag surfaces, is no longer in use.

The EPA also evaluated risk presented by the proximity of ferrous slag to sensitive environments such as wetlands, 100-year flood plains, endangered species habitats, etc. The EPA stated that Fairless Works is located within a 100-year flood plain, which creates the potential for release of slag constituents during floods. In addition, EPA identified on site wetlands at Fairless Works that may be adversely affected by constituents from iron and steel slag. The EPA erroneously stated that Fairless Works is located in a karst (carbonate rock) area, and that groundwater could migrate rapidly in solution cavities. Numerous investigations of the geology at Fairless Works indicate that the site is situated on unconsolidated sands and clays, and that no carbonate rock is present in the subsurface.

In summary, the EPA Report to Congress concluded that the overall, industry-wide, risk from exposure to iron and steel slag constituents is low. The large size and physical/chemical characteristics of slag particles reduce dispersion and leaching potential.

Documented Cases

The final phase of the EPA risk assessment of iron and steel slags involved review of documented cases of environmental damage attributed to these materials. The agency looked at state and EPA regional files describing active and inactive ferrous-metal producing facilities, and conducted interviews with state and EPA regional regulatory staff. Even though iron and steel slags have been generated and managed at many sites for decades, the EPA found only one facility (the former Jones and Laughlin Steel Corporation Aliquippa Works, or LTV Steel) with a documented case of environmental damages associated with ferrous slag.

The reported problems at LTV Steel involved steel slag used as a hazardous waste landfill liner, and iron slag used as fill material at several locations on site. The landfill's slag liner resulted in elevated pH and total dissolved solid (TDS) levels in surface water and groundwater. In another portion of the facility, iron slag impacted groundwater from an area of fill approximately 50 feet thick. These locations increased pH and TDS above the National Pollution Discharge Elimination System (NPDES) permit levels in several seeps.

EPA concluded that ferrous slags pose a low risk to human health and the environment, a conclusion which is supported by the lack of environmental damage documented after decades of onsite and offsite use of slag material.

4.2.3 Conclusions

A wide range of available literature concerning iron and steel slag characteristics, composition, uses, management, potential environmental risk, documented impacts, and regulations was reviewed. The conclusions reached from this review are as follows:

- Ferrous metals slag has been used for decades in engineering and water filtration applications, with considerable success and no reported environmental damage.

- Leachate extracts from iron and steel slags contain various compounds at concentrations well below regulatory levels, and typically below detectable limits.

- Steel slag has cementitious properties that serve to immobilize metal constituents.

- The crystalline silicate and alumino silicate matrices in ferrous slags chemically bind the metal oxides and other compounds in slag, resulting in low-leaching characteristics. Metals in siliceous slag are not present in readily soluble forms.

- The EPA permanently excluded iron slag and steel slag from regulation under RCRA Subtitle C.

- The EPA concluded that iron and steel slags do not exhibit the ignitability, corrosivity, reactivity, and toxicity that are characteristic of hazardous waste.

- The EPA concluded that the potential was low for iron and steel slags to pose a risk to human health and the environment, even assuming very conservative, hypothetical exposure conditions.

- The EPA concluded that potential groundwater releases of slag constituents at Fairless Works would reach a hypothetical exposure point at concentrations below levels of concern.

- The EPA stated that potential release of slag compounds at Fairless Works was unlikely to adversely affect aquatic life or degrade water resources due to the high volumetric flow rate of the Delaware River.

- The EPA concluded that a moderate potential for exposure to airborne slag dusts exists at Fairless Works. However, since the EPA evaluation was performed, major portions of the site have ceased operations, and the potential for erosion is significantly reduced. The agency cited the low tendency of slag to generate respirable-sized dust particles and the high on site precipitation rate that suppresses dust.

- The EPA concluded that slag at Fairless Works could potentially affect on site wetlands, and that the Site was located within the 100-year flood plain.

- The EPA Report to Congress concluded that iron and steel slags are "high-volume, low-hazard" wastes and that the overall, industry-wide, risk from exposure to iron and steel slag constituents is low.

- The EPA's low-risk conclusion was supported by the lack of documented environmental damage cases attributed to ferrous slags, and the wide offsite use of these materials with no reported impact on human health and the environment.

4.3 HISTORICAL DATA

An evaluation of potential groundwater impacts resulting from slag placed at former borrow pits BP-21, BP-31, and BP-31A was provided by U.S. Steel to EPA in 1992. These borrow pits are located northwest of Fairless Works, on a parcel of land sold by U.S. Steel to Waste Management, Inc. in 1988, and reportedly received iron-making slag prior to 1980. The results and conclusions of the evaluation are summarized as follows:

- EP Toxicity, Toxicity Characteristic Leaching Procedure (TCLP), and American Society of Testing and Materials (ASTM) water leaching tests were performed on iron slag samples collected at Fairless Works. The test results indicated that metals do not leach from iron slag at concentrations exceeding regulatory levels.

- Filtered and unfiltered groundwater samples were collected from wells monitoring groundwater quality at former borrow pits BP-21, BP-31, and BP-31A. In filtered samples, metals were not detected at concentrations exceeding maximum contaminant levels (MCLs). Concentrations of several metals exceeded MCLs in unfiltered groundwater samples. The concentrations did not vary considerably over the site, and some of the highest metal levels were detected in the upgradient well. Unfiltered samples were not truly representative of groundwater quality, due to the presence of suspended sediment in the samples (see the discussion of groundwater monitoring results in Section 6.1.7 of this report).

- The TCLP metals concentrations were less than MCLs in a soil sample obtained beneath the slag disposal area. Only zinc and thallium were detected at concentrations exceeding values typical for soils of the United States.

Based on these results, it was concluded that no significant leaching of metals is occurring from iron slag to groundwater at former borrow pits BP-21, BP-31, and BP-31A.

4.4 PHASE I RFI SLAG SAMPLES

Iron and steel slag samples were collected from representative locations at Fairless Works. It was determined from review of U.S. Steel records that iron slag was backfilled in borrow pits BP-21, BP-31, and BP-31A located in the northwest corner of the Site. Steel slag was backfilled in borrow pits BP-23/24/25, NT-1, and NT-2 located near Biles Creek. In accordance with the Phase I RFI Work Plan, one slag sample was collected from each of the six borrow pits. The samples were analyzed for the following list of parameters: Appendix IX metals, TCLP metals, cyanide, sulfide, pH, and oxidation/reduction potential.

Two iron slag samples and three steel slag samples were collected on January 24, 1995. Sample locations are shown on Figure 2-2. Iron slag samples, designated SE-BP-31 and SE-BP-31A, were obtained from borrow pits BP-31 and BP-31A. The third iron slag sample could not be collected during this event, due to a delay in receiving access permission. Steel slag samples were collected from borrow pits BP-23/24/25, NT-1, and NT-2; the samples were designated SE-BP-23-5, SE-NT-1, and SE-NT-2. One quality assurance/quality control (QA/QC) duplicate slag sample was collected at BP-23/24/25, and designated SE-BP-23-5-D. In addition, one QA/QC field rinsate blank sample was collected in the field and analyzed for all of the parameters listed above.

The third and final iron slag sample was collected on March 3, 1995 at BP-21. One QA/QC field rinsate blank sample was also collected during this sampling event.

The analytical results from iron and steel slag samples collected at Fairless Works are provided in Table 4-2. The associated laboratory analytical support documentation is included in Appendix 4-1. Total constituent concentrations detected in Fairless Works slags were similar to data reported for slag at other iron- and steel-producing facilities (Bethlehem Steel Corporation, 1994) and data evaluated by the EPA (Report to Congress, 1990). None of the iron or steel slag, samples contained mercury, antimony, tin, or thallium. Sulfides were identified in iron slag but not in steel slag. In general, the composition of iron slag appeared more variable than the composition of steel slag, although this may be due to the number of samples used in the comparison. Overall, the concentration of a given metal varied by about an order of magnitude among the samples of iron or steel slag.

None of the iron and steel slag TCLP samples contained metal concentrations exceeding TCLP regulatory levels. Silver, arsenic, mercury, and lead were below detection limits for all samples; the other results of the TCLP metals analyses are summarized below:

- Barium was identified in all slag TCLP samples; however, the concentrations were significantly less than the TCLP criterion of 100 milligrams per liter (mg/l). Iron slag TCLP samples contained barium concentrations ranging from 0.390 to 0.711 mg/l, and steel slag TCLP samples contained barium levels ranging from 0.172 to 0.416 mg/l.

- Cadmium was only detected in steel slag TCLP sample SE-NT-2 at a concentration of 0.008 mg/l, a value significantly lower than the TCLP criterion of 1.0 mg/l.

- Chromium was detected in one iron slag TCLP sample at a concentration of 0.008 mg/l, while two steel slag TCLP samples contained chromium at levels ranging from 0.007 to 0.015 mg/l. The TCLP criterion for chromium is 5.0 mg/l.

- Selenium was identified at a concentration of 0.314 mg/l in steel slag TCLP sample SE-NT-2. The TCLP criterion for selenium is 1.0 mg/l.

In conclusion, the Fairless Works slag analytical results indicated the following:

- The composition of iron and steel slag at Fairless Works is similar to the composition of slags reported at other iron- and steel-making facilities.

- Although total metal concentrations in slags may exceed typical background soil levels, the mobility of these metal constituents is low.

- The metals concentrations in slag TCLP samples were significantly below regulatory levels.

4.5 PHASE I RFI SLAG EVALUATION GROUNDWATER SAMPLES

The potential impact of iron and steel slag on groundwater quality was investigated at areas that reportedly contain only slag at Fairless Works. As part of the groundwater investigation, two wells were installed in the USX Industrial Park, designated MW7-12-25 and MW9-1-20, to provide background groundwater quality data (see Figure 2-2). The well construction logs are provided in Appendix 2-3. On April 12 and 13, 1995, groundwater samples were collected from 12 monitoring wells at borrow pits BP-21, BP-31, and BP-31A (iron slag), borrow pits BP-23/24/25, NT-1, and NT-2 (steel slag), and at the USX Industrial Park (background). The monitoring wells included in the slag evaluation are listed in Table 4-3.

Well locations are shown on Figure 2-5. The groundwater samples were analyzed for the following parameters:

- Total metals (Appendix IX List plus iron, magnesium, manganese, potassium, sodium, and calcium)

- Dissolved metals (the amended Appendix IX list as above)

- Trivalent and hexavalent chromium

- Cyanide, group alkalinity, chloride, sulfide, fluoride, nitrate as nitrogen
- Oxidation/reduction potential, pH, specific conductance, dissolved oxygen, and temperature

One QA/QC duplicate groundwater sample was collected MW5-1-26 and analyzed for all of the parameters listed above. In addition, two QA/QC equipment rinsate blank samples were analyzed for all parameters.

The slag evaluation groundwater sample results are presented in Table 4-4. Appendix 4-3 contains the associated laboratory analytical support documentation. The data was compared to the National Primary Drinking Water Regulations (NPDWR) MCLs and secondary maximum contaminant levels (SMCLs). However, as discussed in Section 6.1.6 of this report, these maximum contaminant levels are based on exposure conditions reflecting direct human consumption of water. Groundwater has not been used as a source of water at Fairless Works since the 1950s, because the naturally occurring levels of iron were too high for operational requirements. Since there is no potential for direct consumption of groundwater on the Site, use of these screening criteria is inconsistent with actual exposure conditions.

It is important to note that metal concentrations are higher in unfiltered samples due to the presence of suspended sediment. Unfiltered (total) metal analyses are not representative of migrating groundwater conditions, because suspended sediment does not migrate through the aquifer. Suspended sediment in groundwater samples results from disturbance of the aquifer during well construction and sampling.

The concentrations of chloride, cyanide, fluoride, and nitrate were less than their respective drinking water standards in all of the slag evaluation groundwater samples. The pH levels were slightly less than 6.5 standard units (std. units) in 9 of the 13 samples, including the samples collected at background locations.

Table 4-5 presents a summary of metals concentrations exceeding drinking water standards in the slag evaluation groundwater samples. The concentrations detected in filtered samples are highlighted to indicate the quality of migrating, potable groundwater. Five metals were identified at concentrations exceeding their respective drinking water MCL or SMCL in one or more of the slag evaluation groundwater samples (both unfiltered and filtered samples): iron, manganese, lead, nickel, and chromium. Nickel and chromium levels were also detected in the background well groundwater samples, but the results are not apparently associated with iron- and steel-making slag. The iron/steel slag groundwater samples contained only iron, manganese, and lead at concentrations above drinking water standards. Lead exceeded the action level in only two unfiltered samples.

Dissolved iron concentrations exceeded the SMCL of 0.3 mg/l in one of five steel slag groundwater samples, two of six iron slag groundwater samples, and one of two background groundwater samples. Dissolved manganese concentrations exceeded the SMCL of 0.05 mg/l in four of five steel slag groundwater samples, four of six iron slag groundwater samples, and in both background groundwater samples. The presence of these metals in the background wells indicates that regional groundwater contains elevated iron and manganese levels. Similar iron and manganese levels were identified in groundwater samples pre-dating the construction of Fairless Works, as shown on Table 4-6.

Slightly acidic pH levels also appear to be characteristic of regional groundwater quality. Low pH levels were observed in the majority of the samples, including those collected at both background wells. The range of pH levels was 5.81 to 8.15 standard units (std. units); however, most samples had pH levels slightly below 6.5. The SMCL for pH ranges from 6.5 to 8.5 std. units.

Concentrations of total lead above the NPDWR action level of 0.015 mg/l were detected in two unfiltered groundwater samples, one from the iron slag area and one from the steel slag area. The lead action level is the allowable concentration at the tap. Dissolved lead was not detected in the corresponding filtered samples. Unfiltered groundwater sample MW6-4-29 (steel slag) contained total lead at a concentration of 0.023 mg/l, while sample MW 4 (iron slag) contained total lead at 0.025 mg/l. These results indicate that Fairless Works iron and steel slags do not contribute dissolved lead to groundwater at the Site.

Total nickel was detected at a concentration of 0.12 mg/l in the unfiltered groundwater sample collected at background well MW7-12-25. This level slightly exceeds the MCL of 0.10 mg/l for nickel. Dissolved nickel was not identified in the corresponding filtered sample. Nickel was not identified in the remaining groundwater samples. These results indicate that Fairless Works iron and steel slags do not contribute dissolved nickel to groundwater at the Site.

Chromium was not detected at concentrations above the MCL in the any of the iron or steel slag groundwater samples. The MCL for chromium is 0.1 mg/l. Dissolved chromium was not detected in the steel slag groundwater samples; however, three of the six iron slag groundwater samples contained low levels of dissolved chromium. These levels were significantly below the MCL and ranged from 0.003 to 0.008 mg/l. Hexavalent chromium was not detected in any of the slag evaluation samples. Background groundwater sample MW7-12-25 contained total chromium at a concentration of 0.368 mg/l and dissolved chromium at a concentration of 0.323 mg/l. Chromium in this well is not attributable to iron/steel slag.

In conclusion, the groundwater sample results indicated that iron and steel slags have no significant adverse impact on groundwater quality at the Site. None of the dissolved metal concentrations exceeded drinking water MCLs in iron and steel slag groundwater samples. Only dissolved iron and manganese exceeded SMCLs in slag groundwater samples, and dissolved concentrations of these metals do not pose a long-term risk to human health or the environment. In addition, groundwater in the region has elevated iron and manganese concentrations and a slightly acidic pH. Two unfiltered iron/steel slag groundwater samples contained total lead concentrations that exceeded the drinking water MCL, but the filtered samples, indicative of migrating groundwater quality, were below detection. Dissolved iron, manganese, and chromium were detected at concentrations exceeding drinking water standards in background wells, and these results are not attributed to iron or steel slag.

4.6 ESTIMATION OF SLAG VOLUME

All of the slag produced at Fairless Works was processed by contractors, who removed the magnetic fraction for recycling to the iron and/or steelmaking furnaces, crushed and/or size-graded the balance of the slag, and either sold or used as a commercial product all but the quantities of slag that were too large for such commercial purposes. This arrangement at Fairless Works is typical of the slag processing operations at iron and steel producing facilities, as described in the DOI's 1995 annual report on the iron and steel slag industry:

> . . . the iron- and steelmakers generally contract with other companies to process the slag and to haul it away for sale. Although the arrangements vary, these contracts generally are long term. Commonly, the molten slag is supplied to the processor-hauler gratis, with some modest percentage of the eventual sale revenues returned to the mill. Or, certain high-iron slags may be separated and returned as furnace feed. In the case of steel slags, the valuable entrained steel is recovered by the processor and returned, at below scrap prices, to the steel mill. However, the major processing is simply the controlled cooling of the molten slag at or near the mill and subsequent crushing and screening.

Based on historical steel production records for Fairless Works, approximately 22 million tons of iron-making slag and 16 million tons of steel-making slag was produced from 1955 to 1991. Virtually all of the blast furnace slag was expanded slag, which is used as a lightweight aggregate for construction materials, and has typical unit weights of 35 to 50 pounds per cubic foot (pcf) for the courser aggregates, and 50 to 65 pounds per cubic foot for the finer aggregates. By contrast, the typical unit weight for air cooled steel slag is approximately 75 pcf. Based on the estimated total quantities of slag produced at Fairless Works, and the typical unit weights of the materials, it is estimated that the volume of slag produced at Fairless Works between 1955 and 1991 totaled between 33.1 and 56.6 million cubic yards.

Except for the slag that was recycled for iron and steel production, the slag that was returned to U.S. Steel by the contractors was used as fill material for the backfilling and finish grading of borrow pits, and for the construction of roads and dikes. The estimated volume of those borrow pits that received iron or steel slags at Fairless Works (see Section 3.1 of this report) totals approximately 3.2 million cubic yards. Considering the range of uses to which the slags were put, and the total quantities produced, the actual quantity of slag in the borrow pits is probably less.

The fact that significant quantities of slag have been used on the Site as fill material is not, and should not be viewed as, a cause for concern. In its July 1990 report, EPA advised Congress that:

> The agency used three screening criteria that reflect the potential for hazards to human health, aquatic ecosystems, and water resources . . . Given the conservative (i.e., overly protective) nature of these screening criteria, contaminant concentrations in excess of the criteria should not, in isolation, be interpreted as proof of hazard . . .
>
> . . . [Blast furnace and steel furnace slag] do not exhibit any of the four characteristics of a hazardous waste, and the actual exposure conditions at the active facilities are not as conducive to human health or environmental damage as those upon which the screening criteria are based. This is largely because the slags consist of large solid fragments that are not readily released and dispersed. This finding leads EPA to conclude that the intrinsic hazard of these slags is low.

In 1991, the EPA presented its final regulatory determination that iron and steel slags are not subject to Federal regulation as hazardous wastes. The following year, the PA DEP adopted its Residual Waste Regulations. Under those regulations, the DEP has determined that the use of iron and steel slags for such diverse purposes as material for leveling a parking lot, fill material for construction of a museum, railroad ballast, aggregate for engineered construction fill, underground storage tank backfill, granular fill, and road base, among others, "presents no greater threat of harm to human health and the environment" than would the use of the manufactured or produced materials (i.e., mined and quarried aggregate or fill material) that would have been used if not for the availability of the slag coproduct.

The Phase I RFI analysis of slag at Fairless Works, and of groundwater samples analyzed as part of this slag evaluation, demonstrate that these regulatory determinations of the EPA and DEP relating to the use of iron and steel slag were appropriate. Had the Residual Waste Regulations been promulgated during the period of time when U.S. Steel was using its iron and steel slag for fill material for the backfilling and grading of borrow pits, or the construction of roads and dikes, the material would have been formally designated as a coproduct.

5.0 GROUNDWATER MODELING

5.1 INTRODUCTION

A groundwater model was developed during the Phase I RFI to evaluate the groundwater flow system and predict flow paths from SWMUs and AOCs to the perimeter of Fairless Works. The flow paths were used to establish a groundwater monitoring network designed to assess groundwater quality at the perimeter of the Site from these internal areas.

The groundwater modeling effort took place in steps, which were approved by EPA through report submissions. The scope of work for the groundwater modeling effort was approved by EPA as part of the RFI Work Plan.

The initial groundwater modeling submission to EPA was the "Calibration of the Groundwater Flow Model" report which established the model calibration criteria. A revised version of this submission was approved by EPA on August 24, 1995.

The groundwater flow model was originally submitted to EPA in the "Phase I RCRA Facility Investigation Interim Report." This report contained, among other items, an extensive description of the model calibration including the model framework and inputs, sensitivity analyses, the calibration simulations, the calibrated model output for the selected simulation, a comparison of the calibrated model with the calibration goals, the results of particle tracking using the calibrated model and MODPATH, and an evaluation of the calibration uncertainty. A groundwater monitoring network was proposed based on the modeling results. EPA approved this report and a response to comments in a letter dated July 18, 1996, and required a further submission of "Addendum A - Phase I RFI Interim Report." Addendum A was submitted, reviewed and approved with comments in a letter received by U.S. Steel on September 16, 1996. Four additional wells were drilled before verification of the model took place, three as part of the model verification process, and one as part of the monitoring network.

The verified groundwater model was submitted to EPA in the "Verification of Groundwater Model Report." The model was verified using a second set of head measurements and a refined calibration and particle tracking was submitted to EPA in that report. EPA conditionally approved the report on October 30, 1996, and approved the response to comments on January 7, 1997.

The discussion which follows reflects the groundwater model's development from initiation to completion. Some of the information and data obtained for groundwater modeling was presented in Sections 2.2 and 2.3 (geology and hydrogeology). The groundwater monitoring network and sampling program, which is based on the model and was approved by EPA, is described separately in Section 6.0 of this report.

The primary goal of this groundwater modeling at Fairless Works was to provide information about groundwater flow paths in order to design a groundwater quality monitoring network. The model was constructed at a subregional scale, to determine the site-wide character of the groundwater flow system at Fairless Works. The nature of this modeling effort was interpretive; the intent was to facilitate interpretation of existing data and focus efforts for additional data collection.

5.2 HYDROGEOLOGIC FRAMEWORK

A discussion of the geology and hydrogeology of Fairless Works is presented in Section 2.2 and 2.3 of this report. Information relevant to the groundwater model is reviewed below.

Existing reports about the geology and hydrogeology of the region provide a conceptual understanding of the groundwater conditions at the Site. Two regional reports developed by the U.S. Geological Survey (USGS) and the Pennsylvania Geological Survey describe geology and groundwater resources at the Site (Greenman, *et al.*, 1961; Owens and Minard, 1975), and there are several reports covering adjacent areas (Berg & Dodge, 1981; Eckel & Walker, 1986; Rush, 1968; Vecchioli & Palmer, 1962).

Information regarding the hydrogeology of the Site was collected during various historical environmental investigations of Fairless Works and the surrounding area (Chester Engineers, 1981; Golder Associates, 1988; Chester Engineers, 1988). Additional subsurface investigations were conducted during this Phase I RFI, and the resultant data was incorporated into the groundwater modeling effort.

5.2.1 Geology

The geology at Fairless Works consists of surficial deposits, largely Pleistocene, overlying a Coastal Plain sequence of alternating sands and clays. These unconsolidated deposits overlie crystalline bedrock that is Precambrian or early Paleozoic age. The individual units have been described in detail in Section 2.2 of this report.

For hydrogeologic purposes, the geologic strata which are present at Fairless Works (locally or across the site) can be divided into hydrostratigraphic units, based upon their hydrogeologic characteristics as either water-bearing (aquifers) or confining (aquitards). The hydrostratigraphic units, which do not exactly coincide with the associated geologic units, are listed in Table 5-1, from the surface downward. Geologic units are based on geologic age and other distinguishing stratigraphic characteristics, which may not reflect or distinguish their water-bearing features.

The first major water-bearing unit forms the water table aquifer at the Site. The water table is present beneath the Site at depths ranging from approximately 5 to 20 feet. The water table is present in Pleistocene surficial deposits (Owens and Minard, 1975). Local informal usage denotes these deposits as the Trenton Gravel (Berg and Dodge, 1981). Owens and Minard describe the formation as a "graywacke" consisting of interbedded sand and gravely sand deposits. The material making up this formation is derived from glacial deposits and consists of a variety of source rocks including quartz and quartzites, Triassic sandstones and shales, and limestone.

The water table aquifer also includes younger members of the Coastal Plain deposits, where present. The sands of the Magothy Formation have been identified near the Delaware River (Greenman, *et al.*, 1961). The Old Bridge Sand member of the Raritan Formation has been identified at many locations, and is described as light-gray to yellowish-brown, medium to coarse sand with minor amounts of fine sand and common interbeds of gravel (Greenman, *et al.*, 1961). The Upper Clay member of the Raritan Formation, which would typically separate the Old Bridge Sand from the overlying surficial deposits, is largely absent (Greenman, *et al.*, 1961), and the Old Bridge Sand is hydraulically connected to the overlying Trenton Gravel. The combined thickness is referred to as the water table aquifer.

Locally, the water table aquifer is interrupted by Holocene alluvium consisting largely of organic-rich, dark-colored silts and clays (Owens and Minard, 1975). This material is typically found adjacent to creeks, mudflats, and possibly some portions of the canals that predated development at Fairless Works. Deposits of Holocene alluvium may also be associated with the locations of natural drainage ways which existed prior to development.

The base of the water table aquifer is defined by the Middle Clay member of the Raritan Formation. This clay, which has been identified throughout the Site and surrounding areas, forms a confining unit 10 to over 30 feet thick. The Middle Clay member of the Raritan is a tough, red and white clay with little sand and a generally massive texture (Greenman, *et al.*, 1961). This confining unit overlies the Sayreville Sand or the weathered Wissahickon Saprolite, where the sand is absent. The Middle Clay is the confining unit above the confined aquifer.

The confined aquifer consists of the lower sand member(s) of the Raritan Formation, where present. The Sayreville Sand is a pale yellowish brown deposit of fine to coarse sands with occasional interbeds of light-gray clay (Greenman, *et al.*, 1961). The Sayreville Sand typically overlies the Wissahickon Formation in the vicinity of the Site. However, where the bedrock surface is deeper, the Sayreville Sand overlies a Lower Clay and/or the Farrington Sand members of the Raritan Formation (Greenman, *et al.*, 1961). The Lower Clay consists of interbedded, tough, brick-red clays and softer, gray clays and fine sands; and the Farrington Sand consists of yellowish-gray to pale yellowish-brown, coarse sand and gravel that fines upwards to medium to fine sands with a few beds of white clay (Greenman, *et al.*, 1961.

Greenman et al. (1961) hypothesized that the Farrington Sand may be present in deep bedrock channels, particularly the channel of the ancestral. Delaware which passes through the site. Four deep borings were made to intercept the deep bedrock channel of the ancestral Delaware River. The borings indicated the presence of Farrington Sand at the southeast corner of the site, but the areal extent of the sand is limited. In addition, the Lower Clay separating the Farrington from the Sayreville is present only locally. The combined thickness of the Sayreville and Farrington Sand strata is the confined aquifer.

The base of the hydrostratigraphic section is the Wissahickon Formation (bedrock). The Wissahickon outcrops at the Fall Line, approximately three miles west of the Site, and consists of Precambrian or early Paleozoic mica and hornblende schists and gneisses (Berg and Dodge, 1981). The bedrock surface beneath the site is weathered to a soft, gray, very micaceous clay (Saprolite) which acts as a confining unit below the confined aquifer (Greenman, *et al.*, 1961).

The permeability of the Wissahickon Formation is much lower than the permeability of the confined aquifer or the water table aquifer, and little groundwater flow will take place in the bedrock. Furthermore, the Saprolite provides a confining unit restricting groundwater flow.

5.2.2 Aquifer Boundaries

Fairless Works is bordered on three sides by the Delaware River, which drains a watershed of over 11,000 square miles including portions of five states. According to the USGS, the average flow is about 12,000 cubic feet per second at Trenton, New Jersey, just upstream from Fairless Works (USGS, 1992). Water levels in the Delaware River are subject to tidal fluctuations, and the average range of the tide is approximately 6 to 7 feet in this area (Greenman, *et al.*, 1961).

The River is a regional groundwater discharge boundary to all aquifers. Studies show that the River receives approximately 5 million gallons of groundwater discharge per day along the stretch between Trenton, New Jersey and Newbold Island (CDM, 1982; COE, 1980). Potentiometric levels in the Raritan Formation in this area are above sea level at Fairless Works, and across the River in New Jersey (Eckel and Walker, 1986). Flow is towards the River on both sides.

Bedrock outcropping at the Fall Line (the boundary between the rock formations of the Piedmont Plateau and the unconsolidated sediments of the Atlantic Coastal Plain Physiographic Provinces), and extending below the unconsolidated Raritan sediments, forms the western and the lower natural boundaries for the confining unit and the confined aquifer.

Large areas of the Site and of the surrounding area were excavated to provide sand and gravel. West of the Site, Van Sciver and Manor Lakes (see Figure 1-1) are extensive mined areas that provides water storage in hydraulic connection with the water table aquifer, as described by Greenman, *et al.*, (1961):

> The artificial lakes are important hydrologic features. They interrupt the continuity of the water table and, thus, function as hydraulic boundaries to movement of groundwater in the unconfined aquifers. But they are most important as storage reservoirs. As the lakes are hydraulically continuous with the water-table aquifer, they serve as sources of induced recharge to replenish the aquifers in areas of heavy withdrawal.

The Penn Warner Club manages activities in and around these lakes. Their survey data indicates average water depths of approximately 10 feet in Manor Lake (of which Scotts Creek is a part) and approximately 20 feet in Van Sciver Lake (Penn Warner, 1993). Both lakes extend well into the water table aquifer, providing a western boundary for this aquifer.

5.2.3 Recharge and Discharge

Local precipitation and infiltration is the dominant source of groundwater recharge for the water table aquifer. Due to the sandy nature of the surface soils, most rainfall easily infiltrates. There are impervious areas within Fairless Works where the water table is not able to receive surface recharge, including areas below extensive buildings or paving. Off site, the largest impervious area is the Geological Reclamation Operations and Waste Systems (GROWS) landfill, with its cap and liner system.

The confined aquifer is isolated in the subsurface in a small area between the Fall Line and the Delaware River, which limits the lateral contribution of water from other parts of the Raritan-Magothy aquifer system. Recharge of the confined aquifer in this area is restricted to leakage through the overlying confining unit (the Middle Clay member of the Raritan Formation, from 10 to over 30 feet thick; permeabilities of the clay layers in the Raritan Formation range from 6.16×10^{-8} to 2.72×10^{-7}). There are no known groundwater users in this area, and discharge from both aquifers is to the Delaware River.

The following assumptions were used in development of the groundwater model:

- Rainwater that is not lost as runoff or evapotranspiration recharges the groundwater, or is retained in one of the many bodies of surface water located in the area
- Infiltration recharges the water table aquifer across the Site
- Regionally, groundwater flows from the higher elevations and areas of recharge towards the Delaware River, where it is discharged

5.3 MODEL INPUT

The groundwater flow model was developed using MODFLOW (MacDonald & Harbaugh, 1988). MODFLOW is a finite-difference numerical model, and specific values of inputs must be determined for each model cell.

5.3.1 Model Grid

The size of the model cells was 500 feet in both the *x* and *y* directions. This constant cell size was used throughout the area covered by the grid.

A substantial database of boring and well logs was reviewed and used, where appropriate, to provide input to the model, including the following:

- Geotechnical soil borings prior to plant construction (U.S. Steel, 1951)
- Well logs provided by the USGS (Greenman, *et al.*, 1961)
- Logs for shallow monitoring wells (Chester, 1981)
- Logs for shallow and deep monitoring wells (Golder, 1988)
- Logs for shallow and deep wells installed in the area of the proposed Fairless Landfill (Waste Management of North America [WMNA], 1988)
- Logs for wells installed in "Area B" (Golder, 1988)
- Logs for wells installed around BP-20 as part of its RCRA Closure Plan
- Logs for deep soil borings drilled during the Phase I RFI

The number, extent, and thickness of the model layers was determined from this field information. The water table aquifer was divided into two layers (Layers 1 and 2), allowing for vertical components of flow. The Upper Clay, which is present only locally, was input to the model in the appropriate cells as the leakance term between Layers 1 and 2. The top of the confining unit formed the bottom of Layer 2, and was incorporated in the model as the leakance term between Layers 2 and 3. The confined aquifer formed Layer 3.

The lateral extent of the layers was determined by the presence of hydrologic boundaries. The Delaware River forms a boundary to the east and south for all layers. The extensive lakes form the western boundary to the water table aquifer. The boundaries of the confined aquifer were determined from the data provided in Greenman, *et al.* (1961), supplemented by site-specific information.

Greenman, *et al.* shows that the confined aquifer is interrupted in the center of Fairless Works by the presence of a bedrock high, an interpretation that is consistent with the collected data. Greenman, *et al.* (1961) shows the confined aquifer extending westward in one small lobe. However, deep borings installed where this lobe was supposed to be located did not encounter the confined aquifer. Therefore, the western limit of the confined flow system appears to be located between the Fairfield Works and the lakes. Figures 5-1 and 5-2 show the limits of the water table and confined aquifers in terms of the grid overlain on the site.

5.3.2 Input Parameters

The model inputs for the lateral extent and elevations of the top and bottom of each Layer are shown on Figures 5-3 through 5-6. A three-dimensional depiction of the model layers is shown in Figure 5-7.

Table 5-2 summarizes the input parameter values used for the modeling. The table shows the range of measured values, as well as the range considered for input to the model. The initial input value and the calibrated value is shown.

The values that were selected for hydraulic conductivities were based on hydrogeologic testing performed as part of previous environmental studies at Fairless Works. Chester Engineers (1981) performed constant rate pumping tests for approximately one hour on 14 wells screened in the shallow water table aquifer. Hydraulic conductivities ranged from 0.6 to 370 feet/day, with a geometric mean of 7.2 feet/day.

Slug tests were performed by Golder Associates in 1988 on 16 shallow wells. Six of these wells responded too quickly to obtain useable data; calculated values of hydraulic conductivity for the remaining eight wells ranged from 0.057 to 82 feet/day, with a geometric mean of 2.1 feet/day.

In 1988 (WMNA, 1988), aquifer pumping tests were performed in both the shallow and deep portions of the water table aquifer, and in the confined aquifer. The results of these tests are provided in Table 5-3. Because the results of aquifer pumping tests are more representative of aquifer behavior as a whole, unbiased by local conditions, the hydraulic conductivity values obtained from the pumping tests were used as the initial model inputs.

Values for vertical hydraulic conductivity were initially estimated, based on the characteristics of the individual formations. The lakes were input as constant head cells in Layer 1. The input value of head at each lake was determined from the measured water levels obtained on March 10, 1995. The Delaware River, Biles Creek, and the canals were input as river cells in Layer 1. The input head in each canal was obtained from the field data collected on March 10, 1995. The head in the River and Biles Creek are subject to strong tidal fluctuations, and so were initially assigned mean tidal stage values. The locations of both the constant head cells (lakes) and the river cells for Layer 1 are shown on Figure 5-8. None of these types of cells are present in Layers 2 or 3.

5.3.3 Sensitivity Analyses

An initial sensitivity analyses was used to identify input parameters for which additional field data might need to be obtained. This sensitivity analyses also helped guide the model calibration, by eliminating insensitive parameters from the calibration process.

Fifty-six simulations were run to evaluate sensitivity. Fifteen of these were used to evaluate the northern boundary of the model, which does not correspond to a natural boundary of the aquifers.

Because Van Sciver Lake and the Delaware River are not parallel to each other at the northern end of the model grid, flow lines between the two will be curved. Therefore, the northern boundary of the model is better treated as a curved boundary at an angle to the grid, instead of aligned with the end of the grid. The curved boundary allows simulated groundwater contours to be parallel both to the lakes and to the Delaware River near the northern end of the grid. This shape was used for both Layer 1 and Layer 2 in subsequent simulations. The locations of no-flow cells used to shape this boundary are shown on Figure 5-8. The outline of the grid on Figure 5-1 also reflects this modification.

The model was sensitive to the hydraulic conductivity of Layer 3. An aquifer pumping test had previously been performed for Layer 3 (WMNA, 1988); slug tests were attempted in two deep wells to assess ranges in the hydraulic conductivity of Layer 3. The results of these slug tests are discussed in a previous section of this report.

5.4 CALIBRATION

Calibration demonstrates that the mathematical model adequately reproduces field conditions. The calibration consisted of adjusting model inputs until the hydraulic heads simulated by the model adequately reflected heads measured in the field.

Prior to calibration, it was necessary to obtain a set of water level data from the site. Water levels were collected in the field on March 10, 1995. These data were used to construct a calibration data set (the heads that the model would attempt to adequately reproduce). Wells not screened in the model layers were dropped from the data set. The average head during the tidal cycle was used for wells subject to tidal fluctuations. The list of wells comprising the calibrated data set and their calculated or measured head is provided in Table 5-4. The water level data for the water table aquifer was contoured and is presented in Section 2.3. The water level data from the confined aquifer were not amenable to contouring.

Thirty-eight simulations were performed during calibration. These are summarized in Table 5-5. The calculated correlation coefficients for each simulation are included on this table. The quantitative calibration goal was to achieve a correlation coefficient between the measured and predicted heads of at least 0.80. These values are plotted on the graph on Figure 5-9 to show the improved matching during the calibration process. The residual (or error) is the difference between the predicted and measured head value at each well. For reference, the root mean square residual for each calibration run was also calculated. These values are shown on Figure 5-10.

The simulation selected as the calibrated model is CALIB37. The model output file for this simulation (CALIB37.out) is included in Appendix 5-1. The volumetric water budget shows a discrepancy of 0.01 percent, indicating that mass is conserved.

The measured and predicted head at each well in the calibration data set are shown in Table 5-6. The data show a good match between the measured and predicted head, as indicated by the calculated correlation coefficients presented in Table 5-7. Layer 2 was omitted from the calibration process, as there was only one well set in the deep portion of the water table aquifer (two additional wells were constructed in the deep water table aquifer prior to the verification process).

Figures 5-11 and 5-12 show the simulated heads and groundwater contours for Layers 1 and 3, with the calibration data set posted. The contouring was performed with Surfer (Golden Software, 1994) using kriging, an exponential semi-variogram, and a grid spacing of 500 feet. The simulated groundwater contours for Layer 1 are very similar to the groundwater contour map generated from the field data set (Figure 2-25).

The areal distribution of residuals for Layers 1 and 3 are shown in Figures 5-13 and 5-14, respectively. Scatterplots comparing measured and predicted heads for Layers 1 and 3 are presented in Figures 5-15 and 5-16.

The calibrated values of the input parameters were presented previously in Table 5-2.

In summary, the calibration of Layer 1 was strong, as indicated by the high correlation coefficient. The difference between measured and predicted head is minimal, and the predicted groundwater contours are similar to contours of the measured field data. The hydraulic heads in Layer 1 are dominated by the boundary conditions; specifically, the lakes and the Delaware River and changes to other input parameters have little effect on the resultant heads predicted by the model.

The calibration of Layer 3 was weaker, due to the concentration of calibration data set wells for this layer in one general area of the site. Layer 3 is more sensitive to various input parameters, so the calibration was not a unique solution. In addition to the wells constructed in the deep water table aquifer prior to model verification, an additional well was constructed in the confined aquifer.

5.5 CALIBRATION UNCERTAINTY

Sensitivity analyses were used to evaluate the uncertainty of the model calibration. The following parameters were adjusted during the sensitivity analyses:

- Recharge rate
- Stage of Delaware River, Biles Creek and the canals
- Bed leakance of Delaware River, Biles Creek, and the canals
- Bed elevation of Biles Creek and the canals
- Hydraulic conductivity of each layer
- Leakance between layers

The specific parameter adjustments performed during each simulation are presented in Table 5-8.

The results of these sensitivity analyses were used to quantify the uncertainty of the model calibration. For each new simulation, after a specific parameter was adjusted, the difference between the predicted and measured heads at the wells was calculated and various statistical comparisons were made. The changes in these statistics for the different simulations were used to quantify the uncertainty.

The statistical comparisons included the mean absolute residual, the root mean square residual, and the correlation coefficient. The changes in these statistics for each of the simulations are shown on the graphs in Figures 5-17 and 5-18. These graphs indicate that the model calibration was insensitive to the following parameters:

- Recharge rate
- Bed elevation of Biles Creek and the canals
- Bed leakance of the Delaware River and Biles Creek

Overall, the calibration was sensitive to the head in the river and creek, the permeabilities of the confining unit and Layer 3, and somewhat sensitive to the heads in the canals. On a local scale in the vicinity of the canals, the model is also sensitive to the leakance of the canal beds, and the vertical and horizontal permeabilities of Layers 1 and 2.

The sensitivity to porosity could not be evaluated in the same way, because the porosity does not change the predicted hydraulic heads. The porosity affects the travel time of particles during particle-tracking, which is described in Section 5.7. Two particle-tracking simulations were performed, one with minimum and one with maximum values. The final particle locations for each of these simulations were inspected and compared with the final particle locations using the original porosity values. There was no change in final particle locations based on changes in porosity.

5.6 MODEL VERIFICATION

The purpose of the model verification was to check the model calibration using an independent data set. The new set of field measured water levels was compared to model outputs, and the model was re-calibrated as necessary.

On September 4, 1996, a second round of water level measurements was obtained from wells and surface water bodies at Fairless Works. Three additional wells and a redeveloped well were included in this second data set. From these measurements, a verification data set was generated, as shown in Table 5-9. In addition, the average head was calculated for wells subject to tidal fluctuation in the same manner as described previously.

The collected water level data were used to generate a groundwater contour map for the water table aquifer, which is shown in Figure 2-27. The groundwater contours are an average of about

2 feet higher than the first data set from March 1995, and the general flow patterns are very similar.

Initially, the previously calibrated groundwater flow model was adjusted by changing only the water levels in the surface water bodies to values measured in September 1996. Thereafter, other parameters were adjusted until the predicted heads adequately reproduced the measured heads, just as during the calibration process. Sixteen simulations were performed during the verification process. The adjustments made during each simulation are summarized in Table 5-10. The calculated correlation coefficient for each layer during each of these simulations is also shown in this table. The correlation coefficients and other statistical measures are plotted on the graphs in Figures 5-19 through 5-21, to show the improved fitting throughout the verification process.

The simulation selected as final is VERIF16. The model output file for this simulation (VERIF16.out) is included in Appendix 5-2. The volumetric budget shows a discrepancy of 0.01 percent. The measured and predicted heads at each well are shown in Table 5-11. Figures 5-22 through 5-24 show the simulated heads and groundwater contours for each layer, in addition to the water levels measured in the field. The data show a good match between predicted and measured heads. The correlation coefficients for VERIF16 are shown in Table 5-12.

In addition, the simulated groundwater contours for Layer 1 are very similar to the groundwater contour map generated from the field data (Figure 2-27)

The final verified values of inputs to the model are shown on Table 5-2. During verification, the hydraulic conductivity of the layers was adjusted to improve the fit between measured and predicted heads.

The heads in Van Sciver Lake and Manor Lake were 11.58 and 6.93 feet, respectively, based on water levels measured in the field. Due to the unseasonably wet weather, the verified model included a recharge rate of 15 inches/year, an increase from the calibrated model.

Based on the new set of water levels and actual data from wells in Layer 2, the heterogeneity in Layer 1 was extended to include 27 additional cells in Layer 1 and the same set of cells in Layer 2. The distribution of this change is shown on Figure 5-25.

The verified model, as compared to the calibrated model, provides a more refined representation of groundwater flow conditions at the site, largely because of the additional data from Layers 2 and 3. However, because some input parameters were changed between the calibration and the verification, it was necessary to return to the calibration data set to ensure that these heads could be simulated using the hydraulic conductivities from the verified model. The simulation that addresses this is VERIF17. All inputs were identical to those itemized above except for surface water elevations, which were taken from the March 1995 data set. The calibration coefficients associated with this simulation are shown in Table 5-13. As in the case of the initial calibration, Layer 2 is omitted since the March 1995 data set did not include sufficient wells in the deep portion of the water table aquifer.

These correlation coefficients indicate that the new input parameters are able to adequately match data from both March 1995 and September 1996.

With the additional data obtained after the calibration for Layers 2 and 3, it was possible to evaluate vertical gradients between model layers. Throughout the area covered by the model, little difference was found between heads in Layers 1 and 2, confirming a good connection between them. Furthermore, flow is generally upward from Layer 3 to 2 to 1 in the vicinity of the River, confirming discharge to the River from all layers. At greater distances from the River (such as in the vicinity of the Lakes), flow was found to be downward from Layer 1 to Layers 2 and 3, confirming recharge conditions to all layers at these higher elevations.

In summary, as a result of the model verification, the following input parameters within the calibrated model were refined:

- The hydraulic conductivity of Layer 1 was reduced from 1,000/5,000 feet/day to 700/3,500 feet/day
- The local heterogeneity in the area of the pipe mill was expanded by 27 cells, and a similar heterogeneity was placed in Layer 2
- The hydraulic conductivity of Layer 3 was reduced from 30 feet/day to 10 feet/day

5.7 PARTICLE-TRACKING

The refined (verified) groundwater flow model and the particle-tracking computer code MODPATH (Pollock, 1990) were used to calculate groundwater velocities and pathlines from SWMUs and AOCs. Groundwater flow paths were simulated by placing "particles" at specified locations within the model grid and allowing them to be moved by the groundwater flow system. This movement is calculated and tracked by MODPATH. (Particle tracking was initially performed using the calibrated model with the inputs developed during calibration. The particle tracking results developed using either the calibrated or the verified model were not significantly different.)

Particles were input in SWMUs and AOCs and were spaced at 500-foot intervals, consistent with the model grid spacing. The starting locations of all particles are tabulated in Table 5-14 and shown on Figure 5-26. MODPATH was run to simulate flow of these particles. The particle locations were tracked every 91 days, or four times per year, for a duration of 40 years, in order to determine how groundwater flow paths intersect site boundaries.

Individual pathlines are shown on Figures 5-27 through 5-33, which can be used to evaluate site-wide groundwater flow patterns. It is clear that many of the pathlines exit the site at the most upstream and most downstream sections of the Delaware River adjacent to Fairless Works, and that between these areas, very few pathlines leave the site. This is due to the groundwater mound created by BP-1, which causes many flow lines to diverge around it. Figure 5-34 shows the number of particles discharging into each of the river cells. None of the pathlines extend into Layer 3, the confined aquifer. The pathlines were used to develop the groundwater monitoring network, which is described in Section 6.1.4 of this report. The groundwater monitoring well locations are shown in conjunction with the particle tracks on Figures 5-27 to 5-33.

6.0 PRELIMINARY EVALUATION OF RISK

6.1 GROUNDWATER

6.1.1 Introduction

The Phase I RFI emphasized the evaluation of groundwater because of its importance in assessing risk as a result of potential releases from SWMUs/AOCs at Fairless Works. The proximity of the borrow pits to groundwater in the water table aquifer, the discharge of groundwater from the water table and confined aquifers to the Delaware River, and the protracted boundary with the Delaware River accentuate this point.

The extensive investigation of the physical groundwater flow system at the site was described in Section 5.0 of this report. This section addresses groundwater exposure potential, including the groundwater monitoring well network, groundwater quality screening criteria and their applicability, the analytical results from sampling groundwater, and a comparison of those results to the screening concentrations.

The investigation of groundwater during the Phase I RFI followed a careful and deliberate progression. Geological and hydrogeological investigations were conducted to characterize subsurface conditions. A groundwater flow model was developed from the field information. The model was used to track hypothetical particles along flow paths from SWMUs/AOCs to the perimeter of the site. The groundwater monitoring well network was established at the perimeter in the particle tracks (groundwater pathways) from the SWMUs/AOCs at Fairless Works.

6.1.2 Groundwater Flow

The geology of Fairless Works consists of surficial deposits, largely Pleistocene, overlying a coastal plain Cretaceous sequence of alternating sands and clays. These unconsolidated deposits overlie the Precambrian or early Paleozoic crystalline bedrock, the surface of which is weathered to a soft clay (saprolite).

The first major water-bearing unit forms the water table aquifer. The base of the water table is defined by the "middle clay" member of the Cretaceous sequence, which forms a confining unit 10 to over 30 feet thick across the Site. The confined aquifer below consists of lower Cretaceous sands above the bedrock. In areas of the site which once contained the ancestral channel of the Delaware River, older sequences of Cretaceous clays and sands are present.

Rain water that is not lost as surface runoff or evapotranspiration recharges the groundwater or is retained in one of the many on site open water bodies located at Fairless Works. Infiltration from these water bodies recharges the water table aquifer. Regionally, groundwater in the water table aquifer flows from higher elevations and areas of recharge and storage (i.e., Van Sciver Lake and

Manor Lake) north and west of Fairless Works towards the Delaware River, where it discharges (groundwater elevations and contours which depict groundwater flow are included in this report in Section 2.3).

The confined aquifer is isolated in the subsurface in the small area between the Fall Line and the Delaware River. Recharge is generally restricted to leakage through the overlying confining unit (the middle clay). Groundwater in the confined aquifer discharges to the Delaware River.

Patterns of groundwater flow in the water table aquifer associated with hypothetical particles released from SWMUs/AOCs at Fairless Works were presented in Section 5.7. All particle tracks intercept the Delaware River, and none of the particle tracks extend into the confined aquifer before they reach the Delaware River. Pathways generally converge to exit the Site at the most upstream and downstream locations on the Delaware River adjacent to Fairless Works.

6.1.3 Potential Exposure

Groundwater Wells

Groundwater flows from north and west of Fairless Works in the water table and confined aquifers, across the Site, to the Delaware River. There are no withdrawals of groundwater for potable or non-potable purposes between the upgradient boundary of Fairless Works and the Delaware River (such use was discontinued in the 1950s because the naturally occurring concentrations of iron and manganese were too high, considering the availability of surface water from the Delaware River). Additionally, the minimal saturated thickness of both aquifers at Fairless Works prohibits their use as a potential future source for groundwater supply.

All offsite groundwater supply wells are located either upgradient of Fairless Works or across the Delaware River and separated from Fairless Works by this boundary. There is no potential impact to these wells from activities at Fairless Works.

In order to identify domestic wells or larger capacity supply wells adjacent to Fairless Works, records at the PADEP and NJDEP were reviewed. Telephone contacts were also made with adjacent properties to establish or confirm the existence of wells.

In Pennsylvania, one upgradient domestic well was found within one-half mile of Fairless Works. This well is located at the Fairless Credit Union property, and is active. One upgradient industrial supply well was located within one mile of Fairless Works, at Kohler Air Products; the existence of the Kohler well could not be confirmed.

In New Jersey, three domestic wells are located within one-half mile of Fairless Works, and two industrial water supply wells are potentially within one mile of Fairless Works. The records indicate that one of the domestic wells is located in the water table aquifer (above the middle clay). The water table aquifer in New Jersey is cut off from Fairless Works by the Delaware River. Wells located in the confined aquifer in New Jersey are upgradient of Fairless Works (the aquifer recharges the Delaware River in this area of New Jersey). Table 6-1 lists the Pennsylvania and New Jersey domestic wells within one-half mile and the larger capacity wells within one mile of Fairless Works.

The Delaware River serves as a source of water for treatment and both potable and non-potable water uses. Groundwater discharges from Fairless Works and mixes with surface water in the Delaware Estuary. The estuary also serves as habitat for aquatic and semi-aquatic species, and is used for recreation including boating, swimming, and fishing.

Groundwater is not used at Fairless Works for potable purposes, and there is limited potential and no plans for future potable or non-potable use of groundwater. Groundwater quality concerns from potential exposure arise, therefore, from groundwater discharge to the Delaware Estuary.

The quality of groundwater in monitoring wells at Fairless Works is not representative of the quality of groundwater when it reaches the Delaware River (where exposure occurs). Advective transport will result in additional dispersion and diffusion, and chemical and biological processes will retard migration and attenuate concentrations. These factors will reduce concentrations and loadings from groundwater to the Delaware River by significant factors; additionally, adsorption, dispersion, and volatilization in the Delaware River will further reduce exposure concentrations for aquatic life and humans by factors of 1,800 and 5,000, respectively ("Proposed Media Protective Standards for Corrective Measures, Rohm and Haas Bristol Landfill Sections A, B, and C," BCM Engineers, Inc., August 1990, based on "worst case" model used in a risk assessment for the Delaware River at Bristol, Pennsylvania).

Delaware Estuary - Surface Water Intakes

The Delaware River at Fairless Works (approximately river miles 127 to 130) is a fresh water tidal estuary. The head of tide occurs below the Trenton Falls at river mile 133.4. Although the net flow in the estuary is towards Delaware Bay, the tidal rise causes water to flow upstream during high tide periods. From Fairless Works, upstream flow could potentially extend to the head of tide.

The Delaware River is used as a source of water supply for both potable and non-potable purposes. Surface water withdrawals from the Delaware are controlled by an inter-state agency, the Delaware River Basin Commission (DRBC). Among other functions, the DRBC maintains records of surface water intakes along the Delaware River, and these were reviewed from the head of tide to a point five miles downstream of Fairless Works.

Upstream of Fairless Works, between the Site and the head of tide, there is only one water intake, on the New Jersey side of the river at the PSE&G Mercer Generating Station (river mile 130.5), which uses river water for non-potable purposes (cooling). Downstream (within five miles) of Fairless Works there are three water intakes (excluding U.S. Steel's own intakes at about river mile 127.4, which is discussed below). Two of these intakes, Stepean Company (also on the New Jersey side, at river mile 127.2) and G.R.O.W.S. Landfill (river mile 126.1) withdraw water for non-potable purposes (fire suppressions and dust control, respectively). The third water intake is the Lower Bucks County Joint Municipal Water Authority (LBCA) intake, about five miles below Fairless Works (river mile 122.3), which withdraws about 9 mgd for treatment and potable use.

U.S. Steel has two surface water intakes at Fairless Works, and withdraws water for treatment and potable use and for treatment and non-potable use. Withdrawal for potable use averages 0.7 mgd. Potable water treatment consists of chemical treatment, filtration, and disinfection. Withdrawals for non-potable (cooling) water average 27 mgd. Non-potable water treatment consists of screening and sedimentation.

The Fairless Works surface water intakes, as compared to the other upstream and downstream river intakes, are located at the most sensitive (worst case) location for experiencing potential impacts from any surface water or groundwater discharges to the Delaware estuary from Fairless Works. Tidal dispersion in the estuary of a discharge from Fairless Works will result in greater concentrations at Fairless Works, with lower concentrations upstream and downstream. However, at the Rohm and Haas Landfill site (a similar site downstream from Fairless Works), surface water dispersion modeling in the Delaware River demonstrated reductions ranging up to 5,000 times between the site and the closest intake, 3 miles away.

Further discussion of potential exposure in the Delaware River is presented in Section 6.2.

6.1.4 Monitoring Well Network

A perimeter groundwater monitoring well network was developed, based on the particle-tracking model described in Section 5.7. The model calculated a flowpath, along which a particle in the groundwater would migrate, from a SWMU or AOC to a discharge point at the perimeter of the site. The monitoring well network was established at locations where flowpaths converge along the perimeter of the site. Existing monitoring wells were utilized at suitable perimeter groundwater monitoring points, and additional wells were installed to monitor locations where no well existed. Figures 5-27 through 5-33 show the monitoring well network in relation to the flow paths determined by the particle-tracking model.

The following guidelines were used to establish the monitoring well network:

- Locations where a large number of flow lines converge represent areas where groundwater flow is higher. Because groundwater from a wide area contributes to the point of convergence, monitoring wells at these locations have a higher probability of detecting contaminants, if any are present. Monitoring wells were located where a large number of flow lines converge.

- Flow lines may leave a SWMU or AOC together and remain grouped together to a discharge point at the perimeter. Monitoring wells were located along these paths.

- Flow lines may leave a potential source area and diverge, reaching the perimeter at widely separate locations. Monitoring wells were located along a flow line originating from the center of the SWMU or AOC.

In addition to the wells along the site perimeter, the EPA requested that the monitoring network include a number of wells in the interior. The locations of these wells were also based on the particle-tracking simulations. The following guidelines were used to establish these monitoring well locations:

- Wells were located adjacent to internal hydrologic boundaries, such as the on site canals, to assist in evaluating the potential effects of these features on the groundwater flow system

- Wells were located to provide needed geologic or hydrogeologic information

- A well was located upgradient of potential source areas for sampling background water quality

Table 6-2 lists the 30 wells included in the perimeter network, and the hydrostratigraphic unit monitored. The hydrostratigraphic units monitored by the perimeter network are as follows: 23 wells are screened in the shallow water table aquifer; five wells are screened in the deep water table aquifer; and two wells are screened in the confined aquifer. Twenty of the perimeter network wells were installed prior to the Phase I RFI, and 10 wells were constructed to monitor locations where no well existed. To monitor the shallow water table, 17 existing wells were utilized and 6 new wells were drilled, including one offsite, upgradient well located south of National Can Corporation. One existing and four new wells were installed to monitor groundwater quality in the deep water table aquifer. Groundwater in the confined aquifer was monitored by two existing wells. The location of the monitoring wells is shown on Figure 6-1.

6.1.5 Sampling and Analysis

During the period from December 9 to 19, 1996, one round of groundwater samples was collected from the 30 network monitoring wells. Semivolatile results failed to meet laboratory quality control surrogate criteria and sample re-extraction holding times. As a result, semivolatile data from twenty-five wells were rejected. These wells were resampled for semivolatile analysis from February 17 to 21, 1997.

The groundwater samples were analyzed for the EPA-approved list of analytes shown in Table 6-3. The analytes are based on the RCRA Appendix IX list, excluding certain parameter groups which were not manufactured or used on site (e.g., pesticides) or which lack mobility in groundwater (e.g., PCBs), in accordance with the Phase I RFI Workplan.

6.1.6 Groundwater Quality Screening Criteria

To evaluate groundwater quality, the analytical results from the monitoring well network were compared to screening concentrations. Initially, the Phase I RFI Workplan proposed the RCRA Subpart S Action Levels for screening purposes. EPA suggested the use of the Region III Risk Based Concentrations (RBCs). At the time that the Phase I RFI Workplan was prepared, the January 1993 version of the RBCs was in effect; however, the most recent 1997 Region III RBCs were obtained for use in the evaluation of groundwater in this report.

Screening concentrations are most useful if and when they reflect exposure conditions. At Fairless Works, groundwater discharges to the Delaware River, and the DRBC Surface Water Quality Criteria (SWQC), which were derived from the Federal SWQC, provide additional screening concentrations. Furthermore, because groundwater is not consumed at Fairless Works, the comparison of groundwater quality to drinking water standards, contained in Subpart S and in the Region III RBCs, does not reflect groundwater exposure conditions associated with the facility. The basis and usefulness of each of these sets of screening concentrations is discussed below.

Subpart S Action Levels

In 1990, EPA published Subpart S of Part 264 of the RCRA regulations as a Proposed Rule. Contained within the proposed rule are health based "action levels," triggers for the corrective measures study of various constituent concentrations in air, water and soils. For groundwater, the action levels were based on promulgated standards, principally the maximum contaminant levels (MCLs) established for drinking water under the Safe Drinking Water Act (SDWA), when available. Some action levels were derived from non-promulgated health-based levels which meet four criteria:

1. Derived in a manner consistent with principals and procedure set forth in EPA guidelines for assessing the health risks of environmental pollutants

2. Derived from scientifically valid toxicology studies conducted in accordance with Good Laboratory Practice Standards or equivalent

3. For carcinogens, a $1x10^{-6}$ upper bound excess cancer risk for Class A and B carcinogens and a $1x10^{-5}$ upper bound excess cancer risk for Class C carcinogens

4. For systemic toxicants (toxic chemicals that cause effects other than cancer or mutations), concentrations to which the human population (including sensitive subgroups) could be exposed on a daily basis for a lifetime without the likelihood of experiencing adverse effects.

For constituents without a promulgated MCL, EPA established the action level concentrations by an assessment process which evaluated the quality and weight-of-evidence of supporting toxicological, epidemiological, and clinical studies, and relied on certain exposure assumptions. For water (groundwater or surface water consumption), the exposure assumptions used are 2 liters per day by a 70 kg adult for a 70 year lifetime exposure period. Additional and updated standards (drinking water MCLs) have been promulgated for certain constituents since the 1990 publication of Subpart S, and in this report these more recent standards have been used in place of previously derived Subpart S action levels.

The subpart S action levels are based on exposure conditions reflecting direct human intake of water (they do not address risks associated with aquatic life), and since this condition does not exist for groundwater at Fairless Works, these screening concentrations are conservative. The 10^{-6} upper bound cancer risk level used to generate action levels for carcinogens is in itself conservative, particularly in light of exposure conditions. On the other hand, the Subpart S action levels for water were developed for a single contaminant in a single medium.

EPA Region III Risk Based Concentrations

The EPA Region III RBCs for "tap water" have been devised in a fashion similar to the Subpart S action levels, except drinking Water Standards (MCLs) from the SDWA have not been incorporated. Toxicity constants obtained from the IRIS data base were combined with "standard" exposure scenarios to calculated RBCs -- chemical concentrations corresponding to fixed levels of risk. The risk level for non-carcinogens corresponds to a hazard quotient of one; for carcinogens, a lifetime cancer risk of 10^{-6} is used; and for chemicals which are both, the lower concentration is listed.

The RBCs are "risk assessments run in reverse" (EPA, March 7, 1995) for a single contaminant, in a single medium. The exposure assumptions for water consumption are 2 liters per day for adults 70 kg in weight and 1 liter per day for children 15 kg in weight for a total exposure duration of 30 years. RBCs for volatile compounds with a Henry's law constant greater than 10^{-5} were modified to include inhalation.

Like the Subpart S screening concentrations, the RBCs were developed for residential water consumption, and are conservative screening concentrations with respect to groundwater at Fairless Works. However, they are based on a single contaminant, in a single medium. The RBCs do not consider risks to aquatic life in the Delaware River, where groundwater from Fairless Works discharges. Like the Subpart S action levels, the RBCs are useful for screening purposes, if the derivation of the RBCs, the concentrations found, and the exposure conditions are considered in the comparison.

Delaware River Estuary Water Quality Criteria

The Delaware River Basin Commission (DRBC), through its Delaware Estuary Toxics Management Program, has developed water quality criteria for the protection of aquatic life in the estuary. The criteria are expressed at two levels: a level to protect against acute or short-term effects (1 hour exposure), and a level to protect against chronic or long-term effects (4 day exposure). The DRBC criteria for the protection of aquatic life in the estuary are derived from criteria guidance published by EPA (1976 and 1986 Quality Criteria for Water). The criteria include 12 metals (13 inorganic parameters), 12 pesticides/PCBs, one extractable organic compound and whole effluent toxicity criteria. Six of the metals criteria are presented as formula based on hardness expressed as $CaCO_3$, and the criteria for pentachlorophenal is based on a relationship with pH.

In addition to the criteria for the protection of aquatic life, DRBC has developed surface water quality criteria for the protection of human health, based on drinking water and fish consumption. The estuary is designated for use as a source of public drinking water only in the upper freshwater portion (Zones 2 and 3, Fairless Works being in Zone 2), and these criteria are applicable to the Delaware Estuary at Fairless Works for the protection of human health.

The human health criteria have been developed for protection against both carcinogenic and systemic effects. The criteria for carcinogenic effects utilize an upper bound cancer risk level of 10^{-6} for a 70 kg adult exposed for a lifetime of 70 years. For systemic toxicants, a hazard quotient of one was used. Drinking water consumption was assumed to be 2 liters per day and fish consumption (freshwater) was assumed to be 6.5 grams per day (a 1/3 pound portion every 23 days, or a ½ pound portion every 35 days). These criteria to protect human health were calculated in accordance with EPA's 1991 "Technical Support Document for Water Quality Based Toxics Control."

It should be noted that in Zones 2 and 3 of the estuary, where water is used for drinking purposes, DRBC uses, as water quality criteria, the MCLs (which are incorporated in the Subpart S action levels) when the MCL value is lower than the calculated human health criteria for carcinogenic or systemic effects described above. The MCLs are lower than the calculated criteria for 12 parameters, six metals (antimony, barium, cadmium, chromium (total), nickel, and selenium), four volatile organic compounds (1, 2-trans-Dichloraethene, 1,2-Dichlorapropane, Ethylbenzene and 1,2, 4-Trichlorobenzene), gamma-BHC (lindane) and total trihalomethanes.

DRBC water quality criteria for the protection of aquatic life in the estuary are conservative concentrations for comparison with groundwater quality at Fairless Works. Advective transport of groundwater will result in additional dispersion and diffusion, and chemical and biological processes will retard migration and attenuate concentrations, reducing concentrations and loading to the Delaware by significant factors; additionally, adsorption, dispersion and volatilization in the Delaware River will further reduce exposure concentrations for humans and aquatic life by significant factors (ranging up to 1,800 to 5,000 times or more at a similar site on the Delaware River in Bristol, Pennsylvania).

The concentrations in groundwater have been compared to the DRBC surface water quality criteria for screening purposes in this report. However, reduction in groundwater concentrations by a factor of 1,000 represents a minimal assumption of attenuation prior to exposure which should be considered in the comparison with these criteria.

6.1.7 Groundwater Monitoring Results

The laboratory results and associated laboratory analytical support documentation are provided in Appendix 6-1. As specified in the EPA-approved Phase I RFI Workplan, 50 percent of the data was validated using Region III Modifications to National Functional Guidelines for Data Review, dated February 1994. The data validation reports are included in Appendix 6-2.

Table 6-4 provides a summary of filtered and unfiltered metals results. Antimony, thallium, and tin were not detected in any of the filtered or unfiltered samples from the 30 wells. Generally, the results show low levels of metals in all wells, with a greater number of metals and somewhat higher concentrations detected in unfiltered samples, compared with filtered samples from the same wells (although for some metals, including barium, cadmium, silver, and zinc, a substantial number of the filtered concentrations are higher than the unfiltered concentrations). Metals concentrations in the background well (MW5-41-19) are generally consistent with concentrations detected in many of the other monitoring wells.

Table 6-5 provides a summary of the volatile and semivolatile organic compounds (VOCs and SVOCs) detected. Only 12 VOCs and nine SVOCs were detected in any of the 30 wells, all at relatively low concentrations. Excluding methylene chloride, a common lab contaminant that was detected at concentrations ranging from 2 ug/L to 5 ug/L in all samples, and three wells where a single VOC was detected at concentrations of 1 ug/L or 2 ug/L, VOCs were detected in only seven of the 30 wells. Excluding bis(2-Ethylhexyl)phthalate, another common lab contaminant detected at concentrations from 1 ug/L to 4 ug/L in eight wells, and two wells with a single SVOC detected at 1 ug/L or 2 ug/L, SVOCs were detected in only three of the 30 wells, also at relatively low concentrations.

Only one organic compound, trichloroethene (a VOC), was detected at a concentration above 25 ug/L (and in only one well), and in only seven instances were there VOC or SVOC concentrations exceeding 10 ug/L. Trichloroethene was the only VOC or SVOC detected in more than one well at a concentration above 10 ug/L. Except for methylene chloride, no VOCs or SVOCs were detected in the background well.

In order to evaluate the data, sample results were compared to the previously described screening criteria. The comparisons do not incorporate concentration reductions resulting from mixing, retardation, and other attenuation in groundwater and surface water transport. The groundwater monitoring results are not exposure point concentrations, while the screening criteria were derived for assumed exposure (but to a single contaminant in a single medium). Given the inherently conservative nature of these screening criteria, judgement is required in assessing the results of these comparisons.

Table 6-6 shows pH, specific conductance, and sulfide results in the monitoring well network. The range of pH values is from 4.56 to 8.89 standard units, with an arithmetic mean of 6.46 standard units.

Specific conductance values ranged from 208.87 to 2,822.35 umhos/cm, with an arithmetic mean of 870.82. These results are considered typical of specific conductance values in groundwater in the region.

Sulfide was detected in 4 of 30 groundwater monitoring wells, at levels above detection limits. Two wells, MW2-4-77 and MW3-2-27 in the water table aquifer, had sulfide concentrations (5.09 mg/l and 10.1 mg/l) anomalously above typical levels for the Site.

Total cyanide was detected in3 of the 30 monitoring wells, at levels substantially below the screening criteria (there are no DRBC water quality criteria).

Comparison of Results to Subpart S Screening Criteria

The filtered and unfiltered metals results exceeding both the Subpart S screening criteria and the background well concentrations are shown in Table 6-7. Unfiltered metals concentrations exceeded Subpart S and background concentrations in only seven of the wells, and only three wells had more than a single metal exceedance. The total number of exceedances for unfiltered metals is 14. The numbers of wells and sample results for filtered metals concentrations exceeding both the Subpart S and background concentrations are even lower: a total of only four results in two wells for three metals (beryllium, cadmium and nickel). None of the filtered metals concentrations, and only beryllium, lead and mercury concentrations in the unfiltered samples, exceed the Subpart S criteria in the background well.

The unfiltered metals results reflect the suspension of particulates from the unconsolidated sediments adjacent to the wells. These particulates do not travel in the groundwater. The only pathway for groundwater exposure at Fairless Works is through groundwater discharge to the Delaware River, and filtered samples are more representative of this condition. In general, the metals concentrations exceeding the Subpart S criteria are low, and within an order of magnitude of the screening criteria. The comparisons to Subpart S criteria and background indicate that the potential concern for metals in groundwater is not significant.

The VOCs and SVOCs exceeding the Subpart S screening criteria and background well concentrations are shown in Table 6-8. Only one VOC, trichloroethene, exceeded the criteria, in four of the 30 wells. These wells are located in the northeast quadrant of Site, in the water table aquifer. In general, the concentrations of trichloroethene exceeding the criteria are low, and within an order of magnitude of the screening criteria. The comparison to Subpart S criteria indicates that the potential concern for VOCs and SVOCs in groundwater is not significant.

Comparison of Results to EPA Region III Screening Criteria

The filtered and unfiltered metals results exceeding both the EPA Region III RBC screening criteria and the background well concentrations are shown in Table 6-9. Unfiltered metals concentrations exceeded these criteria and background concentrations in only nine of the wells, and only two wells had more than a single metal exceedance. The total number of exceedances for unfiltered metals is 11. The numbers of wells and sample results for filtered metals concentrations exceeding both the RBC and background concentrations are even lower: a total of only seven results in a like number of wells.

There are only two metals (arsenic and beryllium) for which the results exceed the RBCs, in the case of both filtered and the unfiltered samples. With the exception of the beryllium concentrations in four of the filtered and three of the unfiltered samples, all of the metals concentrations are within an order of magnitude of the RBCs. None of the filtered metals concentrations, and only the beryllium concentration in the unfiltered sample, exceeds the RBCs in the background well.

As discussed above, the filtered metals concentrations are more representative of the potential exposure conditions at Fairless Works, through the discharge of groundwater to the Delaware River. Although the concentrations of arsenic in the filtered samples from four of the wells exceed the RBC, the concentrations are not significant with respect to exposure in the Delaware Estuary. Beryllium concentrations were detected at substantial concentrations in the blanks for both the filtered and unfiltered samples, and the detected concentrations in the well samples may not be representative of actual conditions. Even so, the beryllium concentrations detected in the filtered and unfiltered samples do not appear to be significant with respect to exposure in the Delaware Estuary (they are within the previously noted 1,000 fold or greater reduction for exposure in the estuary).

The VOCs and SVOCs exceeding the RBC screening criteria and background well concentrations are shown in Table 6-10. No VOCs (except methylene chloride, a common lab contaminant reported at a concentration below the RBC) or SVOCs were detected in the background well, and no SVOCs were detected at concentrations exceeding the RBCs in any of the wells. A total of only 11 VOC results exceeded the RBCs, in samples from seven different wells, when the lab contaminant methylene chloride is excluded. None of the VOC exceedances are in the confined aquifer.

Except for trichloroethene, all of the VOCs detected above the RBCs were at low concentrations (2 ug/L to 4 ug/L in five different samples for four VOCs). Trichloroethene exceedances are on the order of 10 to 20 times the RBC in five wells; these exceedances are all within the reduction in concentration expected prior to exposure in the Delaware Estuary and, based on this comparison, the potential concern is not significant.

Comparison of Results to DRBC Surface Water Quality Criteria

DRBC Surface Water Quality Criteria include concentrations protective of aquatic life, some of which are hardness dependent, and concentrations protective of human health, assuming consumption of water and fish from the Delaware Estuary. Five groundwater wells (MW2-3-33, MW2-4-77, MW4-10-23, MW5-41-19, and MW6-6-24) were sampled for hardness, which ranged from 63 to 293, with a geometric mean of 156. This value was used to calculate surface water quality criteria for protection of aquatic life for cadmium, chromium, copper, lead, nickel, silver and zinc. DRBC chronic aquatic life criteria were used except for silver, for which only an acute criterion is available.

The filtered metals results exceeding both the DRBC criteria for protection of aquatic life and human health and the background well concentrations are shown in Table 6-11. No filtered metals concentrations (except mercury) exceed either criteria in the background well.

Filtered metals concentrations exceeded DRBC aquatic life criteria and background concentrations in eight of the wells for four metals (cadmium, nickel, zinc and selenium), and only one well had more than a single metal exceedance; the total number of exceedances is 11. All of the exceedances are less than an order of magnitude above the aquatic life criteria, and considering the expected reduction in concentration prior to exposure, these metals concentrations are not significant.

Only eight of the filtered metals results exceed the DRBC criteria for protection of human health and the background criteria, in samples from the like number of wells. All of these exceedances are limited to arsenic and beryllium, and the exceedances for arsenic are all less than one order of magnitude above the criteria, and within the expected reduction in concentration prior to exposure in the estuary.

Beryllium was detected in blanks, and the concentrations in the well samples may not be representative of actual conditions. Even so, only one of the beryllium concentrations exceeds the minimum 1,000 fold reduction expected between groundwater and the exposure point in the estuary.

VOC and SVOC concentrations exceeding DRBC criteria for protection of human health (there are no aquatic life criteria for VOCs and no SVOC criteria for the compounds detected in the monitoring wells at Fairless Works) are shown in Table 6-12. Nine VOC results exceeded the DRBC human health criteria in samples from six wells. Trichloroethene is the only VOC exceeding the criteria and background concentration detected at a concentration greater than 3 ug/L. Trichloroethene exceeded the DRBC human health criteria in five wells, although the concentrations are less than or only slightly more than an order of magnitude above the criteria. The only SVOC detected above the DRBC human health criteria is bis(2-Ethylexyl)phthalate, a common lab contaminant, and at concentrations of only 2 ug/L to 4 ug/L. No VOCs (except methylene chloride) or SVOCs were detected in the background well. Based on exposure conditions in the Delaware River, the potential exposure to VOCs and SVOCs is not significant.

The DRBC sponsors a surface water monitoring program which includes the Delaware Estuary. Surface water samples are collected at 18 locations in the estuary, including one opposite Fairless Works at river mile 127 (Fieldsboro) and two downstream stations at river mile 118 (Bristol) and river mile 111 (Torresdale). During 1994 and 1995, 120 sampling events were conducted in this zone (Zone 2) of the estuary, from March through November. The sampling results, together with fish consumption advisories, are used to assess the degree that the estuary is able to support its intended uses.

A summary of the assessment for Zone 2 is included in the "Delaware River and Bay Water Quality Assessment 1994-1995 305(b) Report" (DRBC, June 1996). The report indicates that fish consumption was not supported because of PCB, chlordane and mercury contamination; drinking water use was not supported due to the volatile organic 1,2-dichloroethane; and swimming and secondary contact uses were threatened due to exceedances of bacterial limits.

As indicated in the Phase I RFI Workplan, PCBs and the pesticide chlordane were not included among the groundwater monitoring parameters at Fairless Works, because they are not associated with transport in groundwater or with iron and steel making, in general. Groundwater samples from all 30 wells in the monitoring network were analyzed for mercury and 1,2-dichloroethane, and were not detected above surface water quality criteria and background. Bacteria levels in the estuary are not associated with releases from Fairless Works. Based on the results of the DRBC's water quality assessment, there are no impacts to Delaware Estuary surface water quality uses due to groundwater at Fairless Works.

6.1.8 Analysis of Results

As described in the preceding sections, a network of monitoring wells was designed, based on a site-specific groundwater flow model, for the assessment of groundwater quality at the downgradient perimeter of the Site, in order to evaluate potential risks to offsite receptors. It is evident that any conclusions to be reached on the basis of the monitoring results should be considered as preliminary, since the wells in the network have only been sampled once, in accordance with the Phase I RFI Workplan. However, based on the data available at this time, there are two significant conclusions that can be reached.

Offsite Migration

First, there is no threat to human health or the environment as a result of groundwater leaving the Site. Even though groundwater quality at the perimeter was compared to groundwater quality screening criteria that are based on direct consumption (Subpart S criteria and EPA Region III RBCs), there is no potential for the direct consumption of groundwater at Fairless Works, or of the direct consumption of groundwater migrating off site from Fairless Works. All groundwater from Fairless Works flows into the Delaware River Estuary, where attenuation of soluble contaminants will occur before human health or aquatic life exposure can occur.

The only potential human health exposure pathway, as a result of groundwater discharge to the Delaware River, is through swimming, the drinking of water from the Delaware, or the ingestion of fish caught in the Delaware. Thus the most relevant comparison of groundwater quality is to the DRBC's Delaware Estuary Water Quality Criteria, which have been established for both the protection of human health and the protection of the aquatic environment.

As noted in the preceding section, the concentrations in groundwater of the relatively few Appendix IX parameters that exceed either the DRBC human health or aquatic environment criteria and background concentrations are sufficiently low that they will not result in exceedances of the criteria after entering and mixing with the waters of the Delaware River. This is an extremely important outcome of the Phase I RFI, negating any need to consider interim measures related to the offsite migration of groundwater.

It is also an outcome that is confirmed by analyses of the water from U.S. Steel's potable water supply, drawn directly from the Delaware River at a location approximately midway between the confluence of Biles Creek with the Delaware and the confluence of the Central Canal with the Delaware. Finished water from U.S. Steel's potable water plant is analyzed annually for VOCs and every five years for those metals with MCLs included in the National Primary Drinking Water Regulations (antimony, arsenic, barium, beryllium, cadmium, chromium, mercury, nickel, selenium and thallium).

For the most recent analysis of the water supply for metals (February 1995), all of the results were below detection limits except for barium. The detected concentration of barium (23 ug/L) was two orders of magnitude below the MCL for barium (2,000 ug/L), which is also the DRBC water quality criteria for barium. Similarly, the most recent VOC analysis shows that trichloroethylene, the only organic compound of potential concern with respect to groundwater discharges from Fairless Works to the Delaware River, was below detection limits in the finished water for Fairless Works' potable supply.

The most recent Fairless Works potable water data (the nearest point for human consumption of water from the Delaware River) thus confirm that the concentrations of metals, and organic compounds of potential concern, are either below detection limits (with the exception of barium) or below the DRBC water quality criteria for protection of both human health and aquatic life (in the case of barium).

Confined Aquifer

A second significant conclusion that can be reached at this time, on the basis of the initial groundwater monitoring data, is that groundwater in the confined aquifer is of no further concern. No VOCs or SVOCs (except lab contaminants and toluene at 1 ug/L) were detected at all in the confined aquifer, and none of the Appendix IX parameters included in the groundwater monitoring program were found at concentrations exceeding any of the groundwater screening criteria or the DRBC surface water criteria. Thus, any further investigations of groundwater quality in the confined aquifer are not warranted.

Water Table Aquifer

Given these positive initial conclusions from the Phase I RFI groundwater investigation, the remaining discussion related to groundwater results is focused on the water table aquifer monitoring results. These data show sporadic exceedances of screening criteria and background concentrations for a limited number of metals (arsenic, beryllium, cadmium and nickel in the filtered water table aquifer samples, and chromium and lead also in the unfiltered samples). However, with the exception of beryllium, the concentrations are only moderately elevated with respect to the screening criteria, and the beryllium results are blank qualified.

Similarly, there are only sporadic exceedances of the screening criteria and background concentrations for a very small number of VOCs (chloroform, trichloroethene, benzene, and tetrachloroethene), and none for SVOCs. With the exception of trichloroethene, the concentrations of these compounds range from only 2 ug/L to 4 ug/L, and they were detected in only one or (at most) two of the water table aquifer wells (and in one case, chloroform was detected in a duplicate sample only).

More importantly, as noted above in the discussion of offsite migration, there is no potential for the direct consumption of groundwater at Fairless Works; the only potential human health exposure pathway is as a result of groundwater discharge to the Delaware River, and subsequent exposure to the waters of the Delaware River. As already explained, the most relevant comparison of groundwater quality is to the DRBC's Delaware Estuary Water Quality Criteria, which have been established for both the protection of human health and the protection of the aquatic environment. Since concentrations of Appendix IX parameters in the water table aquifer are sufficiently low that they will not result in exceedances of the DRBC human health or aquatic life criteria after entering and mixing with the waters of the Delaware River, there is no threat to human health or the environment associated with groundwater in the water table aquifer.

Although this conclusion is based on data obtained from a monitoring network designed for the assessment of groundwater quality at the downgradient perimeter of the Site, the network is not comprised exclusively of perimeter wells. Five of the water table aquifer wells (MW2-1-22, MW4-11-33, MW4-2-24, and MW5-18-26) are located within the interior of the Site, downgradient of or (in the case of MW2-1-22 and MW4-2-24) within designated SWMUs. Thus the monitoring network provides data related not only to groundwater quality at the perimeter of the Site, but also groundwater quality in the water table aquifer within the Site.

In order to determine whether the concentrations of Appendix IX parameters in these interior water table wells are significantly higher than the concentrations in the perimeter water table wells, the filtered metals data from both sets of wells was compared. To make this comparison on a quantitative rather than a purely subjective (qualitative) basis, discriminant analysis was used in conjunction with nonparametric statistical methods (in this instance, the Mann-Whitney U Test), to test the hypothesis that the well samples from the interior wells and the well samples from the perimeter wells were taken from the same "population" or "universe" (that is, the groundwater sampled from the interior wells and the groundwater sampled from the perimeter wells is statistically the same).

The differentiation of wells as either interior or perimeter constitutes a dichotomous (two-valued) criterion variable that is inherently qualitative. Discriminant analysis is a technique that uses quantitative predictor variables to identify the relationships between such qualitative criterion variables. In the case at hand, the filtered metals concentrations in the well samples were used as the predictor variables for the purpose of discriminating between the two qualitative values (interior well or perimeter well) of the dichotomous criterion variable.

Discriminant analysis uses a linear function to assign a quantitative value on the qualitative criterion variable to each object (in this instance, well sample) in the criterion variable groups (in this instance, interior well or perimeter well). The discriminant function is a derived variable defined as a weighted sum of values on individual predictor variables. Each object's (well sample's) score on the discriminant function (its discriminant score) depends upon its values on the various predictor variables (individual metals concentrations). The form of the discriminant function is thus as follows:

$$L = b_1x_1 + b_2x_2 + \cdots + b_kx_k,$$

where $x_1, x_2, \ldots, x_k$ represent values on the various predictor variables (metals concentrations), and $b_1, b_2, \ldots, b_k$ are the weights associated with each of the respective metals in the samples. The discriminant function is essentially the same as the multiple regression equation used in multiple regression analysis, when the criterion variable is quantitative.

The inverse of the background well concentrations were used as the weights assigned to each of the various predictor variables (metals concentrations) for each well sample. The discriminant function thus took the form:

$$L_{mw} = \frac{[antimony_{mw}]}{[antimony_{bkg}]} + \frac{[arsenic_{mw}]}{[arsenic_{bkg}]} + \cdots + \frac{[zinc_{mw}]}{[zinc_{bkg}]},$$

where $[antimony_{mw}]$ is the concentration of antimony in monitoring well *mw* and $[antimony_{bkg}]$ is the concentration of antimony in the background well, and so forth; L_{mw} is the discriminant score for well *mw* on the discriminant function *L*.

The appropriateness of using the inverse of the background well concentration as the weighting factor for each of the metals in the discriminant function is intuitively obvious: the result is to normalize the monitoring well metals concentrations against the corresponding concentrations in the background well. The discriminate score thus provides an unbiased measure of groundwater quality in each well (as measured by the filtered metals concentrations), relative to background groundwater quality.

The Mann-Whitney U Test was then used to test the null hypothesis that the two sets of sample data (interior wells and perimeter wells) were taken from the same population (groundwater regime), using a directional (one-tailed) alternative hypothesis that the concentrations in the interior wells are significantly higher than those in the perimeter wells. The Mann-Whitney test statistic (U) and its associated z value (indicating the probability of no significant difference between the two data sets) were calculated, based on the discriminant score rank for each of the wells taken collectively, and the sum of the ranks for each of the two separate criterion variable groups (interior wells and perimeter wells). The calculations are included in Appendix 6-3; the observed value of z, and thus the difference between the two sets of groundwater samples, is not significant, and therefore the null hypothesis is not rejected.

It has already been shown that the concentrations of Appendix IX parameters in the perimeter wells are sufficiently low that they will not result in exceedances of the DRBC human health or aquatic environment criteria after entering and mixing with the waters of the Delaware River. Since the concentrations of Appendix IX parameters in the interior wells are not significantly higher than the concentrations in the perimeter wells, it can also be concluded that groundwater in the water table aquifer will not result in such exceedances in the future.

Unlike the broader conclusion that can be reached with respect to the confined aquifer, however, it is too early to conclude that further investigations of groundwater quality in the water table aquifer are unnecessary. Additional sampling of the water table wells in the monitoring well network should be undertaken, to confirm the initial sampling results, address issues raised by blank qualification and duplicate sample disparity, and determine whether there are any significant groundwater quality trends in the water table aquifer over time. The presence of trichloroethene at elevated concentrations in several wells in the northeastern quadrant of the Site should also be evaluated.

6.2 SURFACE WATER

6.2.1 On Site Open Waters

Overview

Potential impacts to on site open waters (i.e., ponds in unfilled or partially backfilled borrow pits) were evaluated using anurans (frogs and toads) as ecological indicators. The approach of focusing directly on sensitive ecological receptors is an alternative to chemical sampling (an indirect process in which relationships between concentrations of numerous chemicals and their potential impacts can only be inferred).

Anurans were selected as an indicator of potential ecological impacts for several reasons. First, anurans are the most abundant vertebrate group associated with the on site open waters. Nine species of anurans are known to be abundant within and adjacent to Fairless Works (wood frog, spring peeper, pickerel frog, Fowlers toad, American toad, green frog, bullfrog, gray treefrog, and cricket frog).

Second, anurans have relatively small home ranges and tend to be faithful to specific open waters. This factor is important in the selection of indicators. Potential impacts indicated by anurans can be attributed to a specific open water. Third, anurans are good indicators of ecological impacts due to their dependence on open water habitats and relatively high degree of sensitivity to pollutants and contamination.

The study of on site open waters using anurans was not designed as a comprehensive study of the population dynamics of individual species or structure of anuran communities. The study was designed as a screening tool to identify on site waters that are potentially impacted ecologically, and as such, the approach was intentionally conservative, to preclude the possibility of not detecting potential impacts.

Methodology

Characterization of Open Waters: The first step in the study of on site open waters was to assess the physical and biological characteristics of the open waters. This information was then used to identify which species of anurans could be expected to inhabit each open water. Characteristics identified for each open water included hydroperiod (duration and frequency of inundation), water depth, size, structure and abundance of vegetation within the open water, and type and structure of adjacent vegetation. Field studies to characterize the open waters were conducted in the fall of 1994. Table 6-13 summarizes these characteristics for each open water.

Assigning Anurans to Open Waters: The species of anurans expected to inhabit each open water were identified *a priori* (i.e., before conducting field surveys for anurans), based on specific habitat requirements identified in the scientific literature and field guides. Table 6-14 summarizes the habitat requirements for eight of the nine anuran species expected to occur at Fairless Works. Wood frog is not included in the list, because this species is an extremely early breeder that calls for a relatively short period of time. These factors, coupled with the large number of open waters, precludes use of the wood frog in the study.

Because the process of assigning species to individual open waters is relatively subjective, it was done conservatively (i.e., biased toward identifying impacts). If habitat requirements for a particular species were marginal, the species was assigned to the open water. Because most of the anuran species at Fairless Works are ubiquitous, conservative assignments were required only for those species with very specific habitat requirements. Gray treefrog requires shrubs and/or trees in or at the edge of water. Fowlers toad requires sandy substrates. American toad requires less than 50 percent vegetative cover overhanging the open water. Absence of a specific habitat feature, such as trees and/or shrubs for gray treefrog, does not necessarily preclude a species from inhabiting a specific open water, but the absence of such features does result in sub-optimal habitat. In instances where habitat was not prohibitive but clearly sub-optimal, the species was not assigned to the open water. Table 6-15 identifies the anurans expected to occur within each open water.

Field Surveys: Field surveys were conducted from March through July in 1995 and from May through June in 1996. The 1995 surveys evaluated all open waters for all species. The 1996 surveys concentrated on diversity in BP-28A, pickerel frog in BP-3, and gray treefrog in BP-27. The objectives of the field surveys were to (1) identify the species of anurans present in each open water and (2) document relative abundance of each species present. The presence of each species was identified by their characteristic calls, which are easily recognized by trained personnel. Relative abundance was documented by recording the relative activity of each species present within an open water. Because of the large size of Fairless Works and the large number of open waters, a simplified index of activity was used, as shown in Table 6-16. The activity index was based on the number of individuals calling, which was easily identifiable by the points of origin of calls.

Times of individual survey events varied, depending on the season and species actively calling. In general, survey events were initiated in late afternoon and continued until approximately mid-night. For most events, two field crews, consisting of two investigators each, conducted the surveys. Approximately one-half of the open waters were surveyed during an event. Time spent at each open water generally ranged from 10 minutes up to 1 hour. The length of time spent at each open water was dependent on the time required to adequately characterize activity for a particular event. For example, less than 10 minutes was required to document a high activity event for spring peeper.

In addition to the on site open waters, investigations were conducted on eight reference sites. The same procedures and methods were used for the reference sites as for the on site open waters. Reference sites, which were visited during each night of investigation, provided a comparison of the statistical analysis discussed below. The eight reference sites used are:

- GROWS
- New Ford Mill East
- New Ford Mill West
- New Ford Mill Northeast
- New Ford Mill Northwest
- Warner North North
- Warner North South
- Warner West

The locations of the reference sites are identified on Figure 6-2. The eight reference sites were selected on the basis of habitat characteristics similar to those of the on site open waters. In addition, previous herpetological studies documented a high abundance and diversity of anurans at these sites. Also, all reference sites are upgradient of surface water and groundwater flow from Fairless Works.

Water Quality: Basic water quality parameters were measured in all on site open waters and reference locations. Measurements were taken using calibrated meters from early May through mid July. Parameters measured were temperature, dissolved oxygen, pH, and specific conductance. Measurements were taken during daylight hours. Any anurans observed or heard calling during the monitoring events were recorded. These observations were not included in the statistical analysis described in the following section.

Data Analysis: The non-parametric Mann-Whitney U-test was used to test for statistically significant differences in activity index between individual on site open waters and the reference sites. The activity period for each species was defined based on the timing of vocalizations at the reference sites and on site open waters. The activity index for the reference sites was compared to the activity index for individual open waters. Dates on which there was no activity at either the individual open water or any of the reference sites were identified as inactive and were not entered into the analysis.

Separate analyses were conducted for each species within an open water. Values of 0, 1, 2, and 3 were used to represent no, low, moderate, and high activity, respectively. Activity for a species within an open water was considered to be below reference levels if a statistically significant difference was detected at the 95 percent confidence level (i.e., the probability of a Type I error was less than 5 percent) using a one-tailed test.

Ranking of Open Waters: As described in the Workplan, open waters were ranked. The assigned rank was based on the presence/absence of species and relative abundance as measured by the activity index and statistical analysis using the Mann-Whitney U-test (as shown in Table 6-17).

The above ranking criteria are extremely conservative. An open water receives a "three" ranking only if all the expected species are present in relative abundances equal to or greater than the reference sites. Absence of a single species, or a relative abundance less than that found at reference sites for a single species, eliminates an open water from a "three" ranking. Furthermore, as discussed above, the assignment of species to open waters was also done in a conservative manner, since a species was assigned to an open water even if habitat was marginal.

Results

Presence/Absence of Species: All nine species of anurans expected to occur at Fairless Works were identified. All but the wood frog were useful in assigning ranks to open waters. As discussed above, the activity season of the wood frog is extremely early and short, making a meaningful comparison of open waters with reference sites impossible. At least two species of anuran were documented in each open water. In BP-39, all species of anurans were present. Table 6-18 provides a summary of the species documented in each open water.

Relative Abundance: An activity index was used to define the relative abundance of each species. For each species present, the activity index for the open water was statistically compared to the comparable activity index for the reference sites using the Mann-Whitney U-test. The Mann-Whitney U-test could not be used for American toad, gray treefrog, and cricket frog, because these species were not calling at any of the reference sites. The presence of any of these species within an open water was interpreted as relative abundance being equal to reference sites. The results of the Mann-Whitney U-test for spring peeper, pickerel frog, Fowlers toad, bullfrog, and green tree frog are summarized in Table 6-19. Complete data on activity for individual open waters and reference sites are provided in Appendix 6-2.

Water Quality: Results of the water quality monitoring are summarized in Table 6-20. Parameters presented include minimum and maximum temperature, minimum and maximum dissolved oxygen, mean specific conductance, and mean pH.

Ranking of Open Waters: Each open water was assigned a rank (1, 2, or 3) based on the presence/absence of expected species and abundance relative to the reference sites. A rank of 1 was assigned to those open waters where 2 or more species were absent and/or occurred at abundances significantly lower ($p < 0.05$) than the reference sites. A rank of 1 suggests likely potential impact to an open water, relative to the reference sites. A rank of 2 was assigned to those open waters where one species was absent or occurred at abundances significantly lower than the reference sites. Open waters with a rank of 2 suggests some or no potential impact. A rank of 3 was assigned to those open waters where all of the expected anuran species were present at abundances equal to or greater than the reference sites. Open waters with a rank of 3 suggests no potential impact. Twenty-one open waters were assigned a rank of 1; 11 a rank of 2; and 9 a rank of 3. Table 6-21 provides a summary of the presence/absence, relative abundance, and ranking for each of these open waters.

Analysis of Results

The evaluation of on site open waters used anurans as indicators of potential ecological impacts. Because the study was intentionally designed to be conservative, the results presented in this section should be interpreted with caution; that is, a ranking of 1 or 2 does not mean that an open water has been significantly impacted by past activities at Fairless Works.

Because the anuran study was developed as a conservative screening tool, several factors that potentially influence the abundance and distribution of wildlife were not incorporated into the design and execution of the study. For example, the degree of non-contaminant related disturbance was not a factor in assigning species to specific open waters. Many of the open waters are island habitats within highly industrialized portions of the site. The degree of isolation and distance to high quality habitat are likely important determinants of the abundance and diversity of anurans supported by these open waters.

Biological factors also need to be taken into account in interpreting the results. For example, BP-28A supports the highest density of bullfrogs of any of the on site open waters or reference sites surveyed. One explanation for the absence of gray treefrog may be due to the high density of bullfrogs, the top predator in the open water. The dense population of predatory bullfrogs may have eliminated or inhibited the vocalizations of treefrogs.

General water quality is another factor that should be taken into account when interpreting the results of the anuran study. Temperature, dissolved oxygen, and turbidly are all factors that can influence the abundance of anurans. For example, BP-37 Central and BP-37 South received rankings of 2 and 1, respectively. Both open waters are located within the forested corridor of the Delaware River, away from past industrial activities, but these open waters are characterized by low levels of dissolved oxygen, which may be the key factor contributing to their rankings.

The results of the anuran study presented above appear to be representative of ecological conditions throughout the site. Unimpacted open waters with a rank of 3 are generally located within the forested corridor of the Delaware River and other relatively undisturbed areas, whereas the potentially impacted open waters with a rank of 1 are generally within the areas of the site where industrial activities have taken place.

The anuran study was designed to be used with other data and information to determine a course of action for the open waters. Rather than expend additional time and effort to further investigate potentially impacted open waters, it is recommended that a corrective measures study be undertaken. The corrective measures study will consider the ecological viability of each impacted open water, including its location within the facility habitat potential and other information. The alternative provision of mitigation areas at more suitable locations will be included in the Corrective Measures Study.

6.2.2 On Site Canals

A macroinvertebrate survey of the East, Central, and West Canals was conducted in the fall of 1995. This survey was performed in accordance with the Phase I RFI Work Plan approved by EPA. Benthic macroinvertebrates were used as bioindicators of potential past and current releases of toxic chemicals from on-site activities. Macroinvertebrates are considered to be a good indicator of such impacts, because most chemicals of concern from the Site (e.g., metals) adsorb to sediments. Thus, compared to other aquatic microhabitats, sediments provide high levels of exposure for macroinvertebrates contained in sediment. Potential impacts to benthic communities in each canal system were assessed by comparing the benthic communities in the canals with control sites which have similar physical characteristics as the canals, and which were selected in conjunction with EPA ecologists.

The primary objective of this investigation was to determine whether the canals potentially impact the Delaware River. Waters from the canals are attenuated significantly in the Delaware River, so that potential toxic conditions in the canals represent a worst case. A secondary objective of the investigation was to determine whether the canals themselves function as healthy aquatic systems. The canals provide moderate to marginal habitat quality, and are generally unnatural areas of shallow depth and low flow.

Site Description

The on-site canals drain surface runoff and non-contact cooling water throughout Fairless Works. The storm water system consists of the East, Central, and West Canals that traverse the Site in a north-south direction, discharging to the Delaware River at the southern boundary of the Site. All three canals consist of an upper region that is not tidally influenced, and a lower region that rises and falls with the tides in the Delaware River. The boundary between tidal and non-tidal regions on each canal is an NPDES-permitted stormwater outfall location. The location of the East, Central, and West Canals are shown on Figure 6-3. As most of the drainage area is flat, and covered with permeable soils that facilitate infiltration of water, the Central and West Canals generally have little flow except during major storms. Thus, these two canal systems resemble very long, narrow and shallow ponds, as opposed to fluvial systems. In contrast, the East Canal receives non-contact cooling water, and generally has a continuous flow.

East Canal: The East Canal begins at the Rod Mill, flows south through BP-1, and then flows approximately 1,100 feet until it discharges into the Delaware River. The canal receives runoff from the areas surrounding the Pipe Mill, Sheet and Tin Mill, Bar Mill, and Rod Mill. Most importantly, the East Canal also receives discharges of non-contact cooling water, and often has a significant flow. The portion of the East Canal below BP-1 is tidal. The banks in the tidal portion of the canal are wooded, with almost complete canopy cover. The substrate in this section consists of a clay hardpan with a large number of *Corbicula* shells and other coarser sediments overlaying the hardpan (Table 6-22). Due to significant flows, aquatic vegetation is almost absent in the lower portion of the East Canal.

Immediately above the tidal portion of the East Canal is a large pond (BP-1), with a fringe of emergent reeds. The substrate in BP-1 consists of slag with a little leaf-litter and organic detritus. Upstream of BP-1, the East Canal is characterized by soft silts and organic detritus with moderate densities of emergent vegetation. This uppermost part of the East Canal receives moderate to high amounts of shade from adjacent forested habitat (Table 6-22).

Central Canal: The Central Canal begins south east of the Central Maintenance Shops and flows south, discharging to the Delaware River east of the Terminal Treatment Plant. This canal receives runoff from the areas surrounding the Sheet and Tin Mill, Administration Area, Central Shops, and Rolling Mill. The lower 600 feet of the Central Canal is tidal. The tidal region has a U shaped channel, with steep banks and a wide flat bottom consisting of deep, very soft, organically rich muck, and sparse to no emergent vegetation. The upper non-tidal portions of the Central Canal are characterized by soft silts and organic detritus, with low densities of emergent vegetation (Table 6-22) The Central Canal receives little shade because its the banks are not forested.

West Canal: The West Canal originates immediately south of BP-5A. Storm water runoff from the areas surrounding the former open hearth furnaces, former blast furnaces, and the former coke plant drains into impoundments west of these areas. The impoundments drain into the West Canal, which discharges to the northern end of the boat slip and to the Delaware River. The lower 200 feet of the West Canal is tidal. The substrate in the tidal portion consists of soft alluvial silts in pools, and gravel and cobble size sediments in runs in the middle of the channel. Dense emergent vegetation is present along the edges of the channel, and in backwater areas. The upstream non-tidal portions of the West Canal are characterized by soft silts with moderately dense areas of emergent vegetation along the banks. The main channel is predominantly devoid of emergent vegetation (Table 6-22). The West Canal is moderately shaded by adjacent forest, especially in the upper reaches.

Control Sampling Locations

Two control stations were identified and sampled. BP-39 was selected as the control site for the upper, non-tidal reaches of the canals. BP-39 is located in the eastern portion of the Site, in the forested floodplain of the Delaware River. BP-39 is a shallow lenticular body of water, approximately 1-2 feet deep. The substrate consists of soft silt and is covered with dense, submerged, aquatic, and filamentous vegetation (Table 6-22). BP-39 receives some shade during morning and evening hours from adjacent forest. BP-39 was considered a good control site because it has no record of contamination, and appears to be undisturbed. In addition, the anuran survey, conducted in the spring and summer of 1995, found BP-39 to have a high density and diversity of frogs species.

Duck Creek was selected as the control site for the tidal portions of the canals. Duck Creek is a tidal tributary to the Delaware River, and is located along the eastern shore of the Delaware River. The Duck Creek sampling station is located on the western shore of Duck Creek, approximately 200 feet from the Delaware River. The substrate consists of fine alluvial silts with some rounded gravel and cobbles. The sampling location contains sparse densities of emergent vegetation, and receives low amounts of shade (Table 6-22). Duck Creek is actually more of an embayment of the Delaware River, as opposed to a tributary. It has almost no watershed and is undeveloped. Duck Creek appears to have no upstream sources of anthropogenic chemicals and represents an ideal control site for the tidal portion of the canals, since it is tidal and representative of ambient Delaware River water chemistry.

Methodology

Macroinvertebrate samples were collected at three stations in each canal and one station in each control location. The location of each sampling station is shown on Figure 6-3. One of the three stations in each canal was located in the tidal portion of the canal, and two of the stations were located in the upper and middle (non-tidal) portions of the canal. To assure that comparable habitats were sampled at each station, samples were taken in soft bottom areas away from emergent vegetation. Soft sediments are the microhabitat with maximum potential exposure to toxic chemicals, as many toxic chemicals tend to adsorb to sediment particles.

At each station, three replicate samples were taken. Samples were collected using a 0.30 meter D-shaped dip net with 0.65-mm mesh size. For each replicate sample, three standard sweeps, about 1 meter in length, were taken with the dip net, which was passed across the benthic surface, collecting approximately the top 5 centimeters of sediments. Collected sediments were then washed in the net in the field. After washing, the macroinvertebrates and remaining sediments were placed in an 80 percent isopropyl alcohol solution. The samples were shipped to the RMC/Normandeau laboratory for sorting and identification. Transfer of samples was documented with standard chain of custody forms. The macroinvertebrates were separated from vegetation and sediments in the lab, and then generally keyed to genus with some taxa being keyed to species.

An attempt was made to standardize the sampling area from replicate to replicate and from site to site. The total area sampled for each replicate sample was approximately 1.0 m^2, with a range of 0.5 to 1.5 m^2. However, the total area and depth of sediments sampled at station E-2 (BP-1) in the middle portion of the East Canal was probably less than at other stations, because of physical constraints and potential safety hazards associated with sampling.

The sampling methods described above represent a modification to the methods proposed in the Phase I RFI Work Plan. During the search for appropriate control sites, it became clear that the on-site canals varied significantly in their physical habitat, structure, and the presence or absence of some microhabitats. As opposed to sampling the various microhabitats at each site, as described in the Work Plan, it was decided to sample the one microhabitat, the soft sediments, common to all sites. These sediments are the most-likely repository for chemicals of concern, if any are present. Prior to field sampling, EPA was notified of this sampling modification in correspondence describing the selection of sampling sites. EPA ecologists subsequently visited the proposed sampling locations, and approved the planned field activities. Similarly, it was decided to sample a constant area as opposed to constant time, because the total time at a sampling station was dominated by washing the sediments from the sample, as opposed to time spent actually collecting the sample.

Taxa richness and density were calculated for each replicate, and a Shannon Diversity Index was calculated for each station. A standard Students t-test using log transformed data was used to compare taxa diversity, density, and taxa richness at each station. Statistically significant differences were identified at the 95 percent confidence level with a one-tailed test (i.e., the probability of making a Type I error is 5 percent).

Results

The results of the benthos sampling for the canal stations and control stations are provided in Appendix 6-5. The Laboratory Identification Bench Sheets providing documentation of QA/QC for the macroinvertebrate identifications are provided as Appendix 6-6. Benthos were observed at all sampling stations. In general, the benthos were dominated by midges, clams, worms, leeches, and scuds (amphipods). Occurring less frequently were dragonflies, bugs, mayflies, beetles, round worms, caddis flies, aquatic sow bugs, and proboscis worms. A summary of the results provided in Appendix 6-5 is presented in Tables 6-23 through 6-25. Although no attempt was made to sample fish, small fish (probably small mumichogs) were also caught at almost all canal stations. Larger fish were noted at several other canal stations (e.g., E-2, E-3).

The three parameters (richness, density and diversity) were tested for significant difference from the appropriate control station, and a summary of the three comparisons is provided in Table 6-26. As can be seen from Table 6-26, the benthos from the tidal Central Canal station was significantly different in all three categories, whereas none of the three parameters was significantly lower for benthos in the tidal portions of the East and West Canals. Of the non-tidal regions, only the middle portion of the Central Canal was not significantly different from BP-39 in any of the three comparisons.

The benthos were also compared qualitatively on the basis of indicator species. The Duck Creek control site was dominated by oligochaetes, clams, midge larvae, and amphipods. This composition also dominated the tidal portion of the West Canal and that of the East Canal, although the tidal portion of the East Canal lacked amphipods (Figures 6-3a, 6-3b, and 6-3c).

The taxanomic composition of all three stations was also consistent with previous sampling of the Delaware River. Between 1970 and 1973, Ichthyological Associates, Inc. collected over 1,085 ponar grabs from the shallows of the Delaware River ("Shallows of the Delaware River: Trenton, New Jersey to Reedy Point, Delaware" by John Tyrawski, 1979). The samples were collected between river mile 116 and 131, which includes the Fairless Works shoreline. Dominant taxa reported by Tyrawski (1979) were the worms Limnodrilus spp. and Peloscolex ferox, the midge larvae Procladius culiciformis, and the clam, Corbicula manilensis. This corresponds to the dominant taxa found at the Duck Creek control station, and tidal portions of West and East Canals. In contrast, the tidal portion of the Central Canal was composed almost solely of oligochaetes, at very low numbers.

Discussion

The species composition of the upstream portions of all three canals is noticeably different from that found in BP-39. BP-39 was dominated by snails and dragonflies, taxa that are associated with the blanket of bottom vegetation at this site, and which is not found in the on-site canals. Because of the significant microhabitat difference between BP-39 and the on-site canals, comparison of indicator species is inappropriate. The fine, soft sediments of the upper canals represent midge and worm habitat, and the upper canals generally contained the taxa that would be expected.

Differences in physical habitat were minimized, but not eliminated, by sampling primarily in the soft sediments at each station. For example, the tidal regions of the West Canal contain primarily fine sediments with some vegetation and some coarse sediments. This corresponds well to conditions found at the Duck Creek control site. However, the sediments in the Central Canal are a deep organic muck that is much heavier and much more difficult to wash than sediments at the other tidal sample stations. In contrast, the sediments in the tidal portion of the East Canal are a thin layer of inorganics underlain by clay hard pan.

The differences in physical habitat among stations is greater with respect to sampling stations in the upper, non-tidal portions of the canals. The upstream canal areas and BP-39 have a soft, silty bottom. However, the bottom of BP-39 is dominated by submerged aquatic plants and filamentous algae that provide substrate and food for aquatic biota. The substrates in the upper canals are either fine sediments (C2, E-3 and W-2), leaf litter with fine sediments (C3 and W3), or leaf litter with little to no sediments (E-2). There is little to no submerged aquatic vegetation in any of the upstream canals habitats. Differences among samples could be due to the different physical and biological habitats. These differences must be taken into account when evaluating the data. For example, the large number of odonate larvae and snails at BP-39 is likely due to the additional habitat provided by submerged vegetation.

Another complication is the occurrence of fish. Fish were not observed in BP-39, and it is unlikely that they occur there. However, fish were noted at all points in the Canals, and predation by fish can also affect the distribution and abundance of macroinvertebrates. Several large carp, which feed primarily on benthos, were seen feeding at sampling site W-2. This could explain the relative scarcity of macroinvertebrates found at this site (Table 6-26).

Considering the differences in physical habitat, some conclusions can be reached. The tidal portions of the West and East Canals appear unimpacted, as they contain species diversity, numerical density, and community composition similar to the Duck Creek control site (Tables 6-23 through 6-25 and Figures 6-3a and 6-3b). Relative to West Canal and Duck Creek control, the tidal portion of the East Canal has no amphipods (Figures 6-3a, 6-3b, and 6-3c). However, the flow regime of the East Canal is different from these other two stations, and for that matter, from any natural system, and the lack of amphipods is largely or totally attributable to the unique flow regimes of the East Canal. Moreover, given the very large flow in this Canal, it is very unlikely that any chemical toxicity could play a large role in the downstream tidal portions without also significantly impacting the same taxa upstream. The benthos of the upstream East Canal stations contained amphipods. The sediments of the East Canal are largely inorganic materials, suggesting that little to no deposition of sediments or previously released chemicals occurs in the tidal portion of the East Canal.

The tidal portion of the Central Canal appears impacted, as it contained few organisms, essentially only oligochaetes. In this case, however, the inhibition of benthic density and diversity could simply be due to the harsh physical environment that occurs in the lower Central Canal: periodic inundation, probably anoxic sediments, wide fluctuations in temperature, etc. Based on the low number of organisms present, this portion of the Central Canal should be considered a higher priority for further investigation.

The data suggest that species density and diversity in the upper portion of the canals are generally comparable to or lower than the control station (BP-39), although the C-2 station had almost twice the density of the control station. Upper canal stations generally had less taxa than the control station, likely due to the more diverse habitat provided by the submerged aquatic vegetation in the control station (BP-39). The fine sediments of the upper canals provide primarily worm and midge habitat, and as expected the non-tidal canal stations are generally dominated by the worms and midge larvae that should dominate such fine sediment habitats. Species density and diversity generally increases with improved habitat in downstream tidal portions of the canals. Moreover, fish were noted at almost all canal stations, so water and sediment quality are apparently sufficient to sustain fish populations and their prey.

The macrobenthos data also indicate that the canals pose no significant threat to the Delaware River. Based on the species composition and densities, sediments in tidal portions of the West or East Canals appear to be non-toxic. The benthos of the tidal Central Canal station appears to have been impacted, but the sediments here are very fine organic muck, indicating that this area is a deposition zone. These sediments are not mobile and do not represent a threat to the Delaware River.

Further Investigation

The sampling stations were ranked on the basis of the following four attributes, and the results are depicted in Table 6-27:

1. Proximity to the Delaware River and potential to impact the Delaware
2. Level of statistical comparability to the control station
3. Level of comparability to expected species composition
4. Potential habitat value

Based on these four criteria, the tidal lower region of the Central Canal represents a priority for further investigation. Sediment bioassays would determine if these sediments are toxic. Bioassays must be designed to consider impacts of other potentially inhibiting factors, including anoxia and high ammonia levels.

The tidal portions of the East and West Canals and the middle section of the Central canal are unimpacted or offer little benthic habitat, and do not require further investigation. Although the benthos from Station W-3 were statistically different in all three population parameters, this station was also accorded a low priority for future investigation, as it has very little habitat potential. This station is essentially just a ditch in the woods, and the impoverished benthos at this station is attributable to limited physical habitat.

The remaining portions of the canals (middle section of the West Canal, the upper section of the Central Canal, and the middle and upper sections of the East Canal) include a combination of impoverished benthos and good to moderate aquatic habitat. These locations are upstream from NPDES sampling points. No further investigation of these locations appears appropriate.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

This Phase I RFI Final Report concludes an extensive investigation of environmental conditions relating to the SWMUs and AOCs at Fairless Works, and more particularly evaluates a number of critical issues regarding impacts or potential impacts to onsite and offsite receptors. The studies, field investigations, groundwater modeling, sampling, and analysis of results which are described in previous sections of this report have produced conclusions useful in establishing needs and priorities for future corrective action tasks. These conclusions are discussed below.

7.1.1 Groundwater

Groundwater has been identified as the critical medium for the potential migration of contaminants to offsite receptors. The investigation focused on understanding site-wide geologic and hydrogeologic conditions. A groundwater model was successfully developed and employed to calculate and depict the flow paths from SWMUs and AOCs to the perimeter of the site. A network of groundwater monitoring wells was established at appropriate points along the Site perimeter, and at internal locations. The perimeter wells were positioned at the most likely locations to detect contaminants released from SWMUs and AOCs. The monitoring well network design, which was based upon the extensive field investigations and groundwater modeling efforts, and was approved by EPA, is heavily biased toward detection of any migratory contaminants at the Site perimeter.

The 30 groundwater monitoring wells employed in the network were sampled for Appendix IX hazardous constituents (except PCBs and pesticides), and the data was compared to two different sets of screening criteria (Subpart S and EPA Region III RBCs), and to the DRBC Surface Water Quality Criteria. In addition, the potential for exposure to groundwater and surface water was assessed. A number of important conclusions are apparent. All groundwater from Fairless Works flows into the Delaware River Estuary, where attenuation of soluble contaminants will occur before human health or aquatic life exposure can occur. There is no potential for exposure to groundwater at Fairless Works from direct ingestion and, consequently, the analysis of groundwater for unfiltered metals (i.e., total recoverable metals) is not relevant.

Particle tracking indicated that contaminants will not reach the confined aquifer, a conclusion that is confirmed by the analysis of samples from the two wells in the confined aquifer. No metals were detected in the confined aquifer above the screening criteria or DRBC water quality criteria. Except for the lab contaminants methylene chloride (2 ug/L to 4 ug/L) and bis(2-Ethylhexyl)phthalate (1 ug/L), and toluene (1 ug/L), no VOCs or SVOCs were found in the confined aquifer, and none of these contaminants exceeded the screening criteria or DRBC water quality standards. Further investigation of groundwater quality in the confined aquifer is not warranted.

Twenty-seven wells in the water table aquifer, at locations biased toward the detection of contaminants from SWMUs and AOCs, and a background well, were sampled. The results show sporadic, low level, exceedances of screening criteria and background concentrations for a limited number of metals (arsenic, beryllium, cadmium and nickel in filtered samples; and chromium and lead, also, in the unfiltered samples). The beryllium concentrations are blank qualified, and all are sufficiently low that they will not result in exceedances of the DRBC water quality criteria after transport to and mixing with the Delaware River.

Similarly, there are only sporadic exceedances of the screening criteria and background concentrations for a very small number of VOCs (chloroform, trichloroethene, benzene, and tetrachloroethene), and none for SVOCs. With the exception of trichloroethene, the concentrations of these compounds vary from only 2 ug/L to 4 ug/L, and they were each detected in only one or at most two wells (chloroform was only detected in a duplicate sample). Again, the concentrations are sufficiently low that, after attenuation, they will not result in exceedances of the DRBC water quality criteria for the Delaware Estuary.

Five of the wells in the water table aquifer are located within the interior of the Site, downgradient of or (in two cases) within SWMUs and AOCs. In order to determine whether the concentrations of Appendix IX parameters in the interior water table wells are significantly higher than the concentrations in the perimeter wells, the filtered metals data from both sets of wells was compared. Discriminant analysis was used in conjunction with nonparametric statistical methods to make this comparison. The analyses indicate that the two sets of groundwater samples are statistically the same, and it can be concluded that groundwater in the water table aquifer will not result in exceedances in the future.

Additional sampling is warranted in the water table aquifer, however, to confirm and further assess trends and conditions. This sampling should include filtered metals for arsenic, beryllium, cadmium and nickel (sampling for total recoverable metals is not relevant to potential exposure conditions) and VOCs. Recommendations concerning additional sampling of groundwater are described subsequently in more detail.

7.1.2 Slag

Section 4.0 of the Phase I RFI Final report provides an evaluation of slag, which was processed and used as backfill and cover material in many of the borrow pits at Fairless Works. Samples of slag were taken from borrow pits at the Site, and of groundwater from monitoring wells installed at these borrow pits. Total metals concentrations in the slag samples were unremarkable; none of the iron or steel slag samples contained detectable mercury, antimony, tin or thallium, and analyses from TCLP tests did not detect silver, arsenic, mercury or lead. Cadmium and selenium were detected in only one of six TCLP sample analyses, at very low concentrations. Chromium was detected in only 50 percent of the TCLP test analyses, at concentrations below the MCL, and although barium was detected in each TCLP sample, the concentrations were well below the MCL.

Results from the groundwater samples confirm the conclusion that slag has not significantly influenced groundwater quality. None of the filtered metals concentrations from the wells exceeded Subpart S screening criteria or drinking water MCLs. Only iron and manganese exceeded SMCLs for the filtered and unfiltered samples. Chromium and nickel slightly exceeded the MCLs in the upgradient unfiltered sample, and chromium also slightly exceeded the MCL in the upgradient filtered sample. The concentrations in the upgradient wells are evidently not associated with slag. Lead, which slightly exceeded the MCL in the unfiltered samples, was not detected in filtered samples (it was also not detected in the TCLP tests), and is not, therefore, effecting groundwater quality.

Results of the sampling and analysis of slag, and groundwater from areas where slag has been placed at Fairless Works, confirm that slag is not a concern. This conclusion is emphasized by EPA's own risk assessment of slag, which determined that slag is "low-hazard" and permanently excluded from regulation as a hazardous waste under RCRA; it is also emphasized by the PA DEP's more recent concurrence with coproduct designations for slag from iron and steel making facilities. In addition to the past uses of slag for commercial and construction purposes, the PA DEP has concurred with its use in the Commonwealth as an aggregate, for fill, as railroad ballast, and as a road base. The slag at Fairless Works was processed and used for the same purposes that the PA DEP now formally endorses.

7.1.3 Surface Water

The ecological assessment for the Phase I investigation of Fairless Works consisted of three components: field investigations of on-site canals; field investigations of on-site open waters; and a review of historical data on biological and chemical sampling of the Delaware River. Investigations of the on-site canals and on site open waters identified areas with ecological impacts that are potentially attributable to past site activities. However, both investigations suggest that any impacts are limited to the Fairless Works site. The review of historical data on the Delaware River indicates that biota of the Delaware River are not impacted by chemical releases from Fairless Works.

In general, Fairless Works supports a surprisingly high diversity of macroinvertebrates and wildlife. Even areas that, on casual observation, appear to be ecologically stressed support some forms of biota. At least two species of anurans were documented in each open water. Several species of macroinvertebrates were documented at all stations within the on-site canals, and fish were also found throughout the canal system. Although some areas had significantly fewer species and individuals than control sites used for the field investigations, the investigations conducted in the Phase I RFI were designed only to identify areas that are potentially stressed. While no attempt was made to identify the causes of stress, some or all of the observed ecological stress identified in the investigations may potentially be attributed to releases, although alternative stressors, such as absence of suitable habitat, also contribute to the observed impacts.

Data for the Delaware River is complicated by several potentially confounding factors. These include tidal influences, an abundance of upstream sources of metals, and the location of Fairless Works adjacent to a deposition zone of the Delaware River. Taking these factors into account, data on surface water and sediment chemistry, water column and sediment toxicity, benthic communities, and fish communities all suggest that the Delaware River adjacent to and downstream of Fairless Works is relatively healthy and unimpacted by chemical releases from the site.

7.1.4 Soils and Waste Materials

Field inspections were made of soil and cover materials at SWMUs and AOCs, to assess conditions and the potential for exposure. No visual evidence of the erosion of cover materials was observed, except at a few locations where surface drainage from roads and open areas is directed into the on site open waters. The coarse size of the slag cover, its subsurface density, and the presence of vegetation, all mitigate against the potential for wind or water erosion. The potential for exposure through volatilization was found at only one borrow pit (BP-35). [redacted]

The potential for worker exposure to hazardous wastes or constituents was also assessed during these inspections. Waste materials in the SWMUs are generally covered, so this potential exposure pathway is not complete. The potential for unintentional worker exposure occurs at SWMUs and AOCs where some waste materials are uncovered, including BP-8A and 8B, BP-10B, BP-13A, and BP-35, and the open tanks and treatment lagoons associated with the industrial wastewater treatment facilities. Although interim measures have been implemented at a number of these borrow pits and wastewater facilities, to reduce the potential exposure for wildlife, final corrective measures are warranted at the borrow pits listed above.

7.1.5 Summary

Overall, the findings and conclusions of this Phase I RFI are positive, particularly with respect to potential threats to offsite receptors. No additional interim measures are warranted at this time to protect human health or the environment. However, additional RFI activities and corrective measures evaluation are recommended in the following section of this report.

7.2 RECOMMENDATIONS

The recommendations that result from completion of the Phase I RFI activities include both additional RFI activities and initiation of corrective measures studies. These recommendations are consistent with the "Technical Approach to the RFI/CMS" that defined the approach to corrective action at Fairless Works, and a logical outgrowth of the findings and conclusions of the Phase I RFI; they represent the next priority for corrective action.

The recommendations and the conceptual approach to the work are described conceptually below. These recommendations may, however, be supplemented in the future, when additional RFI work has been completed. Workplans will be submitted for each of these activities, in accordance with the schedule shown in Table 7-1.

7.2.1 Phase II RFI

Additional RFI activities recommended at this time include the continuation of groundwater sampling and analysis of the Phase I RFI monitoring wells in the water table aquifer; assessment and investigation of VOCs in the northeastern quadrant of the Site; and investigation of the tidal portion of the central canal

Monitoring Well Network Sampling and Analysis

Groundwater sampling of the water table aquifer will be undertaken to confirm the initial sampling results, address QA/QC issues, and determine whether there are any significant groundwater quality trends over time. Groundwater monitoring in the water table aquifer will include the analysis of filtered groundwater samples for arsenic, beryllium, cadmium, and nickel, which were detected above screening criteria and background concentrations, and selenium and zinc, which were detected above the DRBC water quality criteria.

The sampling will be conducted quarterly over a two year period. Following the final sampling event, the analytical data will be compared to the screening criteria and the DRBC water quality criteria, and evaluated for trends in the data. A groundwater assessment report will be submitted, summarizing the results and conclusions of the monitoring program, and presenting recommendations for additional corrective action activities, if any.

Assessment and Investigation of VOCs in Northeast Quadrant

The Phase I RFI has shown that the moderately elevated VOC concentrations in water table aquifer wells in the northeast quadrant of the monitoring well network are not a threat to human health or the environment. An assessment will be conducted to determine whether additional water table aquifer wells are needed to evaluate the source of these VOCs, and whether the concentrations can be expected to decline over time. If appropriate, existing wells will be utilized or new wells constructed, and these wells, together with monitoring wells MW6-6-28, MW6-29-73, MW6-6-24, MW4-11-33 and other wells in the northeast quadrant of the monitoring well network that may provide useful data, will be sampled quarterly over a two year period.

The samples will be analyzed for Appendix IX VOCs. Following the final sampling event, the analytical data will be compared to the screening criteria and the DRBC water quality criteria, and evaluated for trends in the data. A groundwater assessment report will be submitted, summarizing the results and conclusions of the monitoring program, and presenting recommendations for additional corrective action activities, if any.

Central Canal Sediment Bioassays

Investigations of the tidal portion of the central canal will be undertaken to address benthic toxicity. Using bioassay techniques, it should be possible to determine whether the sediments are toxic, and if so, whether this toxicity is due to releases, anoxia, or naturally occurring metabolites.

Since the sediments in the tidal area of the canal appear to be fairly homogenous, bioassaying sediments from three sites (at the upstream end, the middle, and the downstream end closest to the Delaware) should be sufficient to characterize the sediments of the Central Canal. The actual methods (i.e., species, duration, experimental conditions) will be presented to EPA for comment prior to implementation. It is probable that sub-chronic (10 day) bioassays will be conducted with a chironomid and an amphipod (Hyallela sp); however, if whole sediment bioassays prove to be impossible, pore water bioassays may be conducted, instead.

Following completion of the bioassays, a report will be submitted summarizing the results and conclusions of the bioassay study, and presenting recommendations for additional corrective action activities, if any

7.2.2 Corrective Measures Studies

Borrow Pits With Exposed Oil And Tar Residual Material

Borrow pits BP-8A and 8B, BP-10B, BP-13A and BP-35 are SWMUs in which some waste material is exposed. The exposed wastes are oil and tar residual materials with generally similar characteristics. Rather than expending effort and time to further investigate conditions at these SWMUs, it is recommended that a Corrective Measures Study be conducted. In addition, the scale pile located immediately to the east of the Rod Mill Settling Lagoon should be included with these SWMUs for further study.

The workplan for the CMS will include additional investigation, if needed, to evaluate alternatives. The evaluation of alternatives will include, among other possibilities, the consolidation of the waste materials in a Corrective Action Management Unit (CAMU) at BP-35 or other location; covering the exposed waste materials; and removal of the exposed waste materials.

Borrow Pits With Impacted Open Waters

Open water areas in borrow pits were evaluated through a study of anuran population diversity. The protocol used in the study to assess potential impacts to open waters was conservative, since it did not consider the influence on diversity from conditions such as marginal habitat and the existence of barriers to movement, which would tend to limit diversity and population size. Open waters may thus have been identified as potentially impacted, even though impacts may not be related to releases at SWMUs.

Rather than expend effort and time to further distinguish the causes of impacts to the open waters in these borrow pits, it is recommended that a Corrective Measures Study be prepared for the 21 ponds identified as having likely potential impact. The CMS evaluation of alternatives will include the provision of replacement habitat.

TABLE 2-3

SURFACE SOIL SAMPLE ANALYTICAL RESULTS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Sample Designation:		Urban Land (Ub-1)	Urban Land (Ub-2)	Urban Land (Ub-3)	Urban Land (Ub-4)
Sample Date:		10/28/94	10/28/94	10/28/94	10/28/94
Sample Number :		424786	424783	424785	424784
pH	Std. Units	7.40	6.60	7.40	7.50
Total Organic Carbon	mg/kg	6060	11600	5240	2290
Total Solids	%	93.5	93.1	91.5	93.9
Cation Exchange	meq/l	3.2	4.3	3.9	3.0
Remolded Porosity	%	25.9	26.9	26.6	26.4
Liquid Limit/Plastic Limit		IR	IR	18/1	IR
Soil Moisture Content	%	5.6	7.1	8.1	6.8

Sample Designation:		Marsh (MH-1)	Marsh (MH-2)	Urban-Howell (Uh-1)	Urban-Howell (Uh-2)
Sample Date:		10/28/94	10/28/94	10/28/94	10/28/94
Sample Number :		424778	424779	424781	424782
pH	Std. Units	6.10	6.10	6.00	6.10
Total Organic Carbon	mg/kg	93800	105000	2270	9460
Total Solids	%	59.5	58.9	84.9	81.9
Cation Exchange	meq/l	12.1	10.4	5.1	7.8
Remolded Porosity	%	67.6	59.2	34.1	40
Liquid Limit/Plastic Limit		41/6	30/2	22/3	30/10
Soil Moisture Content	%	79.6	53.6	18.2	22.6

Sample Designation:		Pope Loam (PpA-1)	Pope Loam (PpA-2)
Sample Date:		10/28/94	10/28/94
Sample Number :		424777	424780
pH	Std. Units	5.50	5.10
Total Organic Carbon	mg/kg	1730	6200
Total Solids	%	85.9	83.6
Cation Exchange	meq/l	4.1	5.3
Remolded Porosity	%	34.7	37.8
Liquid Limit/Plastic Limit		17/NP	25/3
Soil Moisture Content	%	17.5	18.7

IR = insufficient silt/clay retained by the No. 200 sieve for analysis of liquid/plastic limits
NP = Nonplastic fines
meq/l = milliequivalents per liter
% = percent
Std. Units = Standard Units
Determining Remolded Porosity from Disturbed Samples Results in Estimated Values

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 2-4

SUMMARY OF SOIL SAMPLING ACTIVITIES COMPLETED DURING STRATIGRAPHIC BORING PROGRAM

Sample Designation	Sample Depth (feet below grade)	Stratigraphic Unit	Analysis
DB-2	(71-73)	Middle Clay	Flex Wall Permeability
DB-8	(16-18)	Holocene	Flex Wall Permeability
DB-8	(21-23)	Trenton Gravel	Flex Wall Permeability
DB-8	(86-88)	Middle Clay	Flex Wall Permeability
DB-8	(169-171)	Saprolite	Flex Wall Permeability
DB-2	(19-21)	Trenton Gravel	Porosity, Grain Size
DB-2	(24-26)	Trenton Gravel	TOC, CatX
DB-2	(29-31)	Old Bridge Sand	Porosity, Grain Size
DB-2	(39-41)	Old Bridge Sand	Porosity, Grain Size
DB-2	(74-76)	Middle Clay	TOC, CatX
DB-2	(84-86)	Sayreville Sand	TOC, CatX
DB-2	(89-91)	Sayreville Sand	Porosity, Grain Size
DB-2	(94-96)	Sayreville Sand	TOC, CatX
DB-8	(14-16)	Trenton Gravel	TOC
DB-8	(19-21)	Trenton Gravel	TOC
DB-8	(29-31)	Trenton Gravel	Porosity, Grain Size
DB-8	(34-36)	Trenton Gravel	Porosity, Grain Size
DB-8	(39-41)	Trenton Gravel	TOC
DB-8	(54-56)	Old Bridge Sand	Porosity, Grain Size
DB-8	(54-56)	Old Bridge Sand	TOC
DB-8	(69-71)	Old Bridge Sand	TOC
DB-8	(89-91)	Middle Clay	TOC
DB-8	(119-121)	Sayreville Sand	TOC
DB-8	(144-146)	Farrington Sand	TOC
DB-8	(144-146)	Farrington Sand	Porosity, Grain Size
DB-8	(154-156)	Farrington Sand	Porosity, Grain Size
DB-8	(159-161)	Farrington Sand	TOC
DB-8	(169-171)	Farrington Sand	TOC

TOC - Total Organic Carbon
CatX - Cation Exchange Capacity

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 2-5

DEEP BORING SOIL SAMPLE ANALYTICAL RESULTS

U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Sample Designation:		DB-8	DB-8	DB-8	DB-8	DB-8	DB-8	DB-8
Sample Depth:		(14-16')	(19-21')	(39-41')	(54-56')	(69-71')	(89-91')	(119-121'
Sample Date:		11/2/94	11/2/94	11/3/94	11/3/94	11/3/94	11/4/94	11/4/94
BCM Sample Number:		425753	425754	425755	425756	425757	425758	425759
Parameter	units							
Total Organic Carbon	mg/kg	83500	1690	1020	195	351	1840	262
Cation Exchange Capacity	meq/100 grms	NT	NT	NT	NT	NT	NT	NT

Sample Designation:		DB-8	DB-8	DB-8	DB-2	DB-2	DB-2	DB-2
Sample Depth:		(144-146')	(159-161')	(169-171')	(24-26')	(74-76')	(84-86')	(94-96')
Sample Date:		11/7/94	11/7/94	11/7/94	11/1/94	11/1/94	11/1/94	11/2/94
BCM Sample Number:		425760	425761	425762	425229	425230	425231	425232
Parameter	units							
Total Organic Carbon	mg/kg	207	141	183	663	2770	285	488
Cation Exchange Capacity	meq/100 grms	NT	NT	NT	1.6	4.5	3.5	2.1

Sample Designation:		DB-2	DB-2	DB-2	DB-2	DB-8	DB-8	DB-8
Sample Depth:		(19-21')	(29-31')	(39-41')	(89-91')	(29-31')	(34-36')	(54-56')
Sample Date:		11/1/94	11/1/94	11/1/94	11/2/94	11/3/94	11/3/94	11/3/94
Parameter	units							
Remolded Porosity	%	26	43	36	38	39	26	38

Sample Designation:		DB-8	DB-8	DB-2	DB-8	DB-8	DB-8	DB-8
Sample Depth:		(144-151')	(154-156')	(71-73')	(16-18')	(21-23')	(86-88')	(169-171')
Sample Date:		11/7/94	11/7/94	11/1/94	11/3/94	11/3/94	11/4/94	11/7/94
Parameter	units							
Remolded Porosity	%	35	27	NT	NT	NT	NT	NT
Permeability	cm/sec	NT	NT	3.53E-07	2.72E-07	5.56E-08	6.16E-08	2.95E-07

NT	not tested
mg/kg	milligrams per kilogram
meq/100 grms	milliequivalents per 100 grams
cm/sec	centimeters per second

Note: sample designations in Table 3 correspond to sample designations in Appendix 5 as follows:
DB-8 (Tbl 3) = DB-2 (App. 5) and DB-2 (Tbl 3) = DB-1 (App. 5)

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 2-6

EXISTING GROUNDWATER MONITORING WELLS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Survey Map No.	BCM Well No.	Previous Well No.	Easting	Northing	Elevations Outer Casing	Elevations Inner Casing	Elevations Ground
1	MW1-2-31	17	2806887.19	308847.17	22.80	22.40	19.9
1	MW1-3-27	18	2807994.44	307904.25	22.97	22.07	19.9
1	MW1-5-31	23	2809743.72	308139.17	22.08	21.96	19.3
1	MW1-6-33	24	2810121.62	308081.57	21.39	21.24	18.0
1	MW1-10-32	59	2810104.83	309468.98	22.70	22.53	19.6
1	MW1-12-29	20A	2807218.38	307048.65	19.92	18.59	18.0
1	MW1-14-31	21	2808431.08	307065.21	20.81	20.53	18.2
1	MW1-15-29	24A	2810121.49	308084.06	20.57	20.47	18.0
1	MW1-22-173	DB-8	2808253.73	307033.22	21.25	20.97	18.6
2	MW2-1-22	50	2810460.45	310096.49	22.26	21.64	18.2
2	MW2-2-26	25	2811654.99	309344.21	14.18	13.22	12.3
2	MW2-3-33	61	2811425.16	310810.82	18.30	18.18	15.5
3	MW3-1-24	11	2804833.94	313013.53	20.86	20.82	18.7
3	MW3-2-27	13	2805265.50	313014.36	22.99	21.56	19.9
3	MW3-4-30	16	2806077.45	311445.74	22.60	22.24	20.5
3	MW3-5-27	27	2808557.16	311473.25	22..35	22.27	19.3
3	MW3-12-31	66	2808045.72	313884.40	22.40	22.03	19.0
3	MW3-15-33	60	2809733.48	311515.72	25.21	23.46	21.1
3	MW3-30-30	FUB14	2804702.83	310584.18	21.43	20.85	18.4
3	MW3-34-28	FUB08	2804284.36	312349.78	22.26	21.64	19.4
4	MW4-1-31	28	2809890.10	312311.13	21..02	20.71	18.4
4	MW4-2-24	30	2810652.04	311868.69	17.52	17.49	13.6
4	MW4-3-23	29	2810245.30	311782.30	15.80	15.78	12.0
4	MW4-4-25	31	2811054.93	312753.16	22.65	22.43	20.0
4	MW4-5-27	33	2812222.92	314647.01	11.69	10.94	8.7
4	MW4-6-32	34	2810757.21	314665.08	23.59	23.48	20.3
4	MW4-9-29	63	2810255.76	313240.08	22.58	22.22	19.9
4	MW4-10-23	65	2814097.21	314247.24	13.01	12.79	9.5
4	MW4-11-33	64	2809787.90	314905.55	23.39	23.20	19.5
4	MW4-14-36	87	2811919.16	314858.61	15.46	15.06	12.1
4	MW4-15-119	88	2811921.70	314847.89	15.35	14.75	12.2
4	MW4-17-47	FUP03	2811943.95	314725.94	15.07	14.59	12.4
4	MW4-18-34	FUA03D	2811750.85	315093.80	16.93	16.37	14.3
4	MW4-21-101	FUA02D	2811754.45	315086.14	17.32	16.78	14.3
4	MW4-27-103	FUA01D	2811938.03	314732.30	15.31	14.78	12.3
4	MW4-29-132	PTP2D	2812595.34	314916.31	13.20	12.74	10.5
4	MW4-30-63	PWS	2812653.10	314970.16	9.95	NS	9.2
4	MW4-31-132	PWD	2812644.30	314982.35	11.92	NS	9.9
5	MW5-1-26	5	2802834.61	315606.44	21.79	21.35	19.3
5	MW5-2-24	6	2803380.58	316195.71	21.86	21.66	19.1
5	MW5-3-21	8	2802918.32	314311.13	19.01	18.48	15.7
5	MW5-5-27	7A	2803723.19	313978.32	23.85	22.75	20.1
5	MW5-6-16	9	2803251.03	313034.10	15.09	14.53	12.5
5	MW5-7-24	7	2804194.72	314784.65	22.83	22.75	19.6
5	MW5-11-27	43	2806654.00	317422.01	22.67	22.36	20.1
5	MW5-12-27	46	2804869.80	316474.00	21.74	21.47	18.5
5	MW5-13-27	47	2806207.53	316156.36	19.69	19.23	17.1
5	MW5-15-32	8A	2802921.09	314300.58	18.18	17.95	15.7
5	MW5-16-16	9A	2803248.61	313032.92	15.78	12.88	12.4
5	MW5-18-26	70	2804409.44	315635.17	22.90	22.63	19.7
5	MW5-24-80	TB-1D	2803280.15	315082.54	22.37	21.42	20.4
5	MW5-30-77	TB-4D	2803748.02	314540.61	20.93	20.62	18.2

TABLE 2-6

EXISTING GROUNDWATER MONITORING WELLS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Survey Map No.	BCM Well No.	Previous Well No.	Easting	Northing	Elevations Outer Casing	Inner Casing	Ground
5	**MW5-35-15**	MW-11	2803739.32	317035.60	16.55	NS	NS
5	**MW5-36-82**	FUB05D	2803542.33	312748.79	16.94	16.40	14.4
5	**MW5-37-29**	FUB04	2803539.44	312756.99	17.27	16.74	14.2
6	**MW6-1-32**	36	2811052.63	315698.88	23.50	23.41	20.5
6	**MW6-2-27**	38	2809535.62	318384.92	15.44	15.16	12.9
6	**MW6-4-29**	53	2808759.49	317537.52	23.45	23.16	20.1
6	**MW6-5-28**	39	2808466.92	318220.77	22.09	21.95	19.5
6	**MW6-6-24**	37	2810845.88	317951.00	18.47	18.29	16.8
6	**MW6-7-28**	78	2812822.23	317020.55	17.62	16.74	14.5
6	**MW6-8-28**	79	2810188.78	318398.52	15.15	14.98	12.7
6	**MW6-12-42**	FUP02	2811277.99	316459.85	20.17	19.65	17.3
6	**MW6-13-30**	FUA05	2811438.82	316047.28	15.64	15.04	12.8
6	**MW6-17-109**	FUA04D	2811559.59	315606.95	17.56	17.08	14.3
6	**MW6-18-113**	FDP14D	2812451.93	316956.12	8.91	8.41	5.5
6	**MW6-20-37**	FUP01R	2811555.71	315613.40	17.73	17.31	14.9
6	**MW6-23-24**	MW-2	2810913.93	316541.26	22.92	22.05	20.6
6	**MW6-24-20**	MW-3	2811063.00	315925.22	23.05	22.15	20.3
6	**MW6-26-20**	MW-7	2809348.23	318374.23	22.74	21.67	20.2
6	**MW6-28-23**	MW-6	2809693.24	315400.49	21.60	20.61	19.9
7	**MW7-1-26**	1	2804519.68	317311.53	21.94	21.68	19.4
7	**MW7-3-21**	3	2801254.18	316838.50	19.94	NS	NS
7	**MW7-4-26**	42	2807166.27	318365.76	22.65	22.43	19.8
7	**MW7-5-28**	44	2806049.82	318626.95	23.00	22.75	20.4
7	**MW7-8-17**	MW-3	2804079.67	317201.79	18.53	18.25	15.9
7	**MW7-9-17**	MW-4	2804127.24	317293.09	19.38	18.83	16.8
7	**MW7-10-17**	MW-10	2803779.81	317066.03	17.23	NS	NS
7	**MW7-12-25**	NS	NS	NS	NS	NS	NS
9	**MW9-1-20**	NS	NS	NS	NS	NS	NS
9	**MW9-2-28**	NS	NS	NS	NS	NS	NS
1	**SG-1**		2805255.63	309138.82	NS	NS	9.89
1	**SG-2**		2809770.72	308394.74	NS	NS	9.50
2	**SG-3**		2811148.46	310684.32	NS	NS	9.73
6	**SG-4**		2809931.87	318790.88	NS	NS	16.63
offsite	**SG-5**		2798685.68	312264.88			
offsite	**SG-6**		2798778.98	311877.69			

Notes

NS = not surveyed due to absence of inner casing, lack of access, or well constructed after survey

1. All Easting and Northing rounded to two decimal places.
2. SG-1 through SG-3 measurement is from top of gauge; SG-4 is from benchmark in tree.
3. Data for SG-5 and SG-6 from spreadsheet i:\usx\rfi\wells\existing.xls.

TABLE 2-10

CALCULATED TIME-WEIGHTED MEAN GROUNDWATER ELEVATIONS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

UNCONFINED AQUIFER

Well	Well	Measured Head in Well Hm (feet MSL)	Time of Measurement 3/10/95 Tm (hrs:min)	3/10/95 Tm (days)	Distance to Delaware River x (feet)	Mean unconfined T/S (ft^2/day)	Time Lag Well tr (days)	3/10/95 4:02 TIME of Low Well TL	3/10/95 9:27 TIME of High Well TH	3/10/95 16:50 TIME of Low Well TL	3/10/95 22:01 TIME of High Well TH	Mean unconfined T/S (ft^2/day)	Stage Ratio 1/2 range (feet)	Stage Ratio full range Ro (feet)	Time initial days (days)	Time final days (days)	Time measured days Tm (days)	head initial feet	head final feet	head average feet
MW1-2-31	17	3.13	9:53	0.4118	1565	3.00E+05	0.5832	3/10/95 18:01	3/10/95 23:28	3/11/95 6:49	3/11/95 12:00	3.00E+04	1.67E-09	3.34E-09						
MW1-3-27	18	2.68	9:47	0.4076	1100	3.00E+06	0.4100	3/10/95 13:52	3/10/95 19:17	3/11/95 2:40	3/11/95 7:51	3.00E+04	1.20E-06	2.40E-06						
MW1-14-31	21	2.90	10:26	0.4347	305	3.00E+06	0.1137	3/10/95 6:45	3/10/95 12:10	3/10/95 19:33	3/11/95 0:44	3.00E+04	9.15E-02	1.83E-01	0.2817	0.5074	0.4347	2.776	2.959	2.867
MW1-16-29	24A	2.84	10:46	0.4488	255	3.00E+06	0.0950	3/10/95 6:18	3/10/95 11:43	3/10/95 19:06	3/11/95 0:17	3.00E+04	1.86E-01	3.71E-01	0.2631	0.4888	0.4486	2.535	2.906	2.720
MW1-5-31	23	2.82	10:39	0.4438	620	3.00E+06	0.2311	3/10/95 9:34	3/10/95 14:59	3/10/95 22:22	3/11/95 3:33	3.00E+04	1.06E-03	2.13E-03						
MW1-6-33	24	3.43	10:47	0.4493	255	3.00E+06	0.0950	3/10/95 6:18	3/10/95 11:43	3/10/95 19:06	3/11/95 0:17	3.00E+04	1.86E-01	3.71E-01	0.2631	0.4888	0.4493	3.124	3.495	3.309
MW1-10-32	59	3.71	10:59	0.4576	1250	3.00E+06	0.4659	3/10/95 16:12	3/10/95 20:37	3/11/95 4:00	3/11/95 9:11	3.00E+04	1.44E-07	2.87E-07						
MW1-12-29	20A	2.74	10:18	0.4292	190	3.00E+06	0.0708	3/10/95 5:43	3/10/95 11:08	3/10/95 18:31	3/10/95 23:42	3.00E+04	4.65E-01	9.31E-01	0.2389	0.4646	0.4292	1.955	2.886	2.421
MW2-2-26	26	2.63	11:10	0.4653	50	3.00E+06	0.0186	3/10/95 4:28	3/10/95 9:53	3/10/95 17:16	3/10/95 22:27	3.00E+04	3.37E+00	6.74E+00	0.4124	0.7200	0.4653	3.789	-2.951	0.419
MW2-3-33	61	-1.04	11:17	0.4701	1170	3.00E+06	0.4360	3/10/95 14:29	3/10/95 19:54	3/11/95 3:17	3/11/95 8:28	3.00E+04	4.45E-07	8.91E-07						
MW3-1-24	11	6.50	12:43	0.5299	5600	3.00E+06	2.0870	3/12/95 6:07	3/12/95 11:32	3/12/95 18:55	3/13/95 0:06	3.00E+04	2.76E-34	5.52E-34						
MW3-2-27	13	12.27	12:37	0.5257	5670	3.00E+06	2.1131	3/12/95 6:44	3/12/95 12:09	3/12/95 19:32	3/13/95 0:43	3.00E+04	1.03E-34	2.05E-34						
MW3-4-30	16	4.79	12:34	0.5236	4000	3.00E+06	1.4907	3/11/95 15:48	3/11/95 21:13	3/12/95 4:36	3/12/95 9:47	3.00E+04	1.85E-24	3.70E-24						
MW3-5-27	27	3.61	13:14	0.5514	3780	3.00E+06	1.4087	3/11/95 13:50	3/11/95 19:15	3/12/95 2:38	3/12/95 7:49	3.00E+04	4.16E-23	8.31E-23						
MW3-12-31	66	4.08	13:20	0.5556	5730	3.00E+06	2.1355	3/12/95 7:17	3/12/95 12:42	3/12/95 20:05	3/13/95 1:16	3.00E+04	4.39E-35	8.78E-35						
MW3-15-33	60	4.52	13:30	0.5625	2920	3.00E+06	1.0882	3/11/95 6:09	3/11/95 11:34	3/11/95 18:57	3/12/95 0:08	3.00E+04	7.96E-18	1.59E-17						
MW3-30-30	FUB14	4.82	13:01	0.5424	4000	3.00E+06	1.4907	3/11/95 15:48	3/11/95 21:13	3/12/95 4:36	3/12/95 9:47	3.00E+04	1.85E-24	3.70E-24						
MW3-34-28	FUB08	5.92	12:53	0.5368	4900	3.00E+06	1.8261	3/11/95 23:51	3/12/95 5:16	3/12/95 12:39	3/12/95 17:50	3.00E+04	5.49E-30	1.10E-29						
MW4-14-36	87	2.48	11:06	0.4625	2270	3.00E+06	0.8460	3/11/95 0:20	3/11/95 5:45	3/11/95 13:08	3/11/95 18:19	3.00E+04	7.81E-14	1.56E-13						
MW4-5-27	33	2.44	10:53	0.4535	1950	3.00E+06	0.7267	3/10/95 21:28	3/11/95 2:53	3/11/95 10:18	3/11/95 15:27	3.00E+04	7.21E-12	1.44E-11						
MW4-6-32	34	2.69	10:39	0.4438	3420	3.00E+06	1.2746	3/11/95 10:37	3/11/95 16:02	3/11/95 23:25	3/12/95 4:36	3.00E+04	6.76E-21	1.35E-20						
MW4-9-29	63	3.07	11:56	0.4972	3720	3.00E+06	1.3864	3/11/95 13:18	3/11/95 18:43	3/12/95 2:06	3/12/95 7:17	3.00E+04	9.71E-23	1.94E-22						
MW4-10-23	65	2.73	11:49	0.4924	130	3.00E+06	0.1262	3/10/95 7:03	3/10/95 12:28	3/10/95 19:51	3/11/95 1:02	3.00E+04	3.24E-01	6.47E-01	0.2843	0.5200	0.4924	2.162	2.809	2.486
MW4-2-24	30	4.05	12:09	0.5063	2460	3.00E+06	0.9168	3/11/95 2:02	3/11/95 7:27	3/11/95 14:50	3/11/95 20:01	3.00E+04	5.32E-15	1.06E-14						
MW4-3-23	29	3.90	12:17	0.5118	2690	3.00E+06	1.0025	3/11/95 4:05	3/11/95 9:30	3/11/95 16:53	3/11/95 22:04	3.00E+04	2.06E-16	4.11E-16						
MW4-4-25	31	3.35	12:01	0.5007	2850	3.00E+06	1.0621	3/11/95 5:31	3/11/95 10:56	3/11/95 18:19	3/11/95 23:30	3.00E+04	2.14E-17	4.28E-17						
MW4-1-31	28	3.73	12:05	0.5035	3320	3.00E+06	1.2373	3/11/95 9:43	3/11/95 15:08	3/11/95 22:31	3/12/95 3:42	3.00E+04	2.78E-20	5.56E-20						
MW4-18-34	FUA03D	2.29	11:00	0.4583	2220	3.00E+06	0.8274	3/10/95 23:53	3/11/95 5:18	3/11/95 12:41	3/11/95 17:52	3.00E+04	1.58E-13	3.17E-13						
MW4-17-47	FUP03	2.46	11:14	0.4681	2230	3.00E+06	0.8311	3/10/95 23:58	3/11/95 5:23	3/11/95 12:46	3/11/95 17:57	3.00E+04	1.38E-13	2.75E-13						
MW4-30-63	PWS	2.56	11:26	0.4764	1410	3.00E+06	0.5255	3/10/95 16:38	3/10/95 22:03	3/11/95 5:26	3/11/95 10:37	3.00E+04	1.50E-08	2.99E-08						
MW4-11-33	64	2.76	10:28	0.4361	4420	3.00E+06	1.6473	3/11/95 19:34	3/12/95 0:59	3/12/95 8:22	3/12/95 13:33	3.00E+04	4.88E-27	9.75E-27						
MW6-15-32	8A	9.46	13:45	0.5729	8200	3.00E+06	3.0560	3/13/95 5:22	3/13/95 10:47	3/13/95 18:10	3/13/95 23:21	3.00E+04	2.97E-60	5.93E-60						
MW6-6-16	9	7.63	13:54	0.5792	6800	3.00E+06	2.5342	3/12/95 16:51	3/12/95 22:16	3/13/95 5:39	3/13/95 10:50	3.00E+04	1.18E-41	2.35E-41						
MW6-16-16	9A	7.52	13:51	0.5771	6800	3.00E+06	2.5342	3/12/95 16:51	3/12/95 22:16	3/13/95 5:39	3/13/95 10:50	3.00E+04	1.18E-41	2.35E-41						
MW6-7-24	7	7.42	13:15	0.5521	8200	3.00E+06	3.0560	3/13/95 5:22	3/13/95 10:47	3/13/95 18:10	3/13/95 23:21	3.00E+04	2.97E-60	5.93E-60						

TABLE 2-10 (Continued)

CALCULATED TIME-WEIGHTED MEAN GROUNDWATER ELEVATIONS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

UNCONFINED AQUIFER

Well	Well	Measured Head in Well Hm (feet MSL)	Time of Measurement 3/10/95 Tm (hrs:min)	3/10/95 Tm (days)	Distance to Delaware River x (feet)	Mean unconfined T/S (ft^2/day)	Time Lag Well tr (days)	3/10/95 4:02 TIME of Low Well TL	3/10/95 9:27 TIME of High Well TH	3/10/95 16:50 TIME of Low Well TL	3/10/95 22:01 TIME of High Well TH	Mean unconfined T/S (ft^2/day)	Stage Ratio 1/2 range (feet)	Stage Ratio full range Ro (feet)	Time initial days (days)	Time final days (days)	Time measured days Tm (days)	head initial feet	head final feet	head average feet
MW5-5-27	7A	7.64	13:24	0.5583	7450	3.00E+05	2.7766	3/12/95 22:40	3/13/95 4:05	3/13/95 11:28	3/13/95 16:39	3.00E+04	1.20E-45	2.40E-45						
MW5-12-27	46	6.20	12:42	0.5292	7000	3.00E+05	2.6088	3/12/95 18:38	3/13/95 0:03	3/13/95 7:26	3/13/95 12:37	3.00E+04	6.95E-43	1.39E-42						
MW5-11-27	43	4.87	12:28	0.5194	4950	3.00E+05	1.8448	3/12/95 0:18	3/12/95 5:43	3/12/95 13:06	3/12/95 18:17	3.00E+04	2.71E-30	5.42E-30						
MW5-13-27	47	5.94	12:36	0.5243	6450	3.00E+05	2.4038	3/12/95 13:43	3/12/95 19:08	3/13/95 2:31	3/13/95 7:42	3.00E+04	1.66E-39	3.32E-39						
MW5-18-26	70	6.80	13:10	0.5486	8200	3.00E+05	3.0560	3/13/95 5:22	3/13/95 10:47	3/13/95 18:10	3/13/95 23:21	3.00E+04	2.97E-50	5.93E-50						
MW5-2-24	8	11.55	14:00	0.5833	8750	3.00E+05	3.2610	3/13/95 10:17	3/13/95 15:42	3/13/95 23:05	3/14/95 4:16	3.00E+04	1.24E-53	2.48E-53						
MW6-8-28	79	1.60	11:39	0.4854	1600	3.00E+05	0.5963	3/10/95 18:20	3/10/95 23:45	3/11/95 7:08	3/11/95 12:19	3.00E+04	1.02E-09	2.04E-09						
MW6-7-28	78	1.46	11:22	0.4736	175	3.00E+05	0.0652	3/10/95 5:35	3/10/95 11:00	3/10/95 18:23	3/10/95 23:34	3.00E+04	5.75E-01	1.15E+00	0.4590	0.7668	0.4736	1.616	0.364	0.939
MW6-6-24	37	1.52	11:34	0.4819	1410	3.00E+05	0.5255	3/10/95 16:38	3/10/95 22:03	3/11/95 5:26	3/11/95 10:37	3.00E+04	1.50E-08	2.99E-08						
MW6-5-28	39	1.76	9:46	0.4069	3010	3.00E+05	1.1218	3/11/95 6:57	3/11/95 12:22	3/11/95 19:46	3/12/95 0:56	3.00E+04	2.23E-18	4.46E-18						
MW6-4-29	53	1.76	9:52	0.4111	3170	3.00E+05	1.1814	3/11/95 8:23	3/11/95 13:48	3/11/95 21:11	3/12/95 2:22	3.00E+04	2.32E-19	4.64E-19						
MW6-28-23	MW-6	1.82	10:30	0.4375	3680	3.00E+05	1.3715	3/11/95 12:56	3/11/95 18:21	3/12/95 1:44	3/12/95 6:55	3.00E+04	1.71E-22	3.42E-22						
MW6-26-20	MW-7	12.05	9:57	0.4146	3490	3.00E+05	1.3007	3/11/95 11:14	3/11/95 16:39	3/12/95 0:02	3/12/95 5:13	3.00E+04	2.51E-21	5.02E-21						
MW6-24-20	MW-3	1.72	10:17	0.4285	2270	3.00E+05	0.8460	3/11/95 0:20	3/11/95 5:45	3/11/95 13:08	3/11/95 18:19	3.00E+04	7.81E-14	1.56E-13						
MW6-23-24	MW-2	1.67	10:21	0.4313	2070	3.00E+05	0.7715	3/10/95 22:32	3/11/95 3:57	3/11/95 11:20	3/11/95 16:31	3.00E+04	1.32E-12	2.64E-12						
MW6-20-37	FUP01R	1.62	10:47	0.4493	2040	3.00E+05	0.7603	3/10/95 22:16	3/11/95 3:41	3/11/95 11:04	3/11/95 16:15	3.00E+04	2.02E-12	4.04E-12						
MW6-2-27	38	1.50	11:41	0.4868	2200	3.00E+05	0.8199	3/10/95 23:42	3/11/95 5:07	3/11/95 12:30	3/11/95 17:41	3.00E+04	2.10E-13	4.21E-13						
MW6-13-30	FUA05	1.79	10:58	0.4569	1880	3.00E+05	0.7006	3/10/95 20:50	3/11/95 2:15	3/11/95 9:38	3/11/95 14:49	3.00E+04	1.94E-11	3.88E-11						
MW6-12-42	FUP02	1.58	11:04	0.4611	1770	3.00E+05	0.6596	3/10/95 19:51	3/11/95 1:16	3/11/95 8:39	3/11/95 13:50	3.00E+04	9.20E-11	1.84E-10						
MW6-1-32	36	1.71	10:12	0.4250	2390	3.00E+05	0.8907	3/11/95 1:24	3/11/95 6:49	3/11/95 14:12	3/11/95 19:23	3.00E+04	1.43E-14	2.86E-14						
MW7-4-26	42	3.08	11:54	0.4958	3730	3.00E+05	1.3901	3/11/95 13:23	3/11/95 18:48	3/12/95 2:11	3/12/95 7:22	3.00E+04	8.43E-23	1.69E-22						
MW7-5-28	44	4.24	12:03	0.5021	4650	3.00E+05	1.7330	3/11/95 21:37	3/12/95 3:02	3/12/95 10:25	3/12/95 15:36	3.00E+04	1.89E-28	3.77E-28						
MW7-1-26	1	5.51	12:22	0.5153	6600	3.00E+05	2.4597	3/12/95 15:03	3/12/95 20:28	3/13/95 3:51	3/13/95 9:02	3.00E+04	1.99E-40	3.98E-40						
MW7-9-17	MW-4	5.97	12:26	0.5181	6950	3.00E+05	2.5901	3/12/95 18:11	3/12/95 23:36	3/13/95 6:59	3/13/95 12:10	3.00E+04	1.41E-42	2.82E-42						
MW7-10-17	MW-10	6.12	13:16	0.5528	7350	3.00E+05	2.7392	3/12/95 21:46	3/13/95 3:11	3/13/95 10:34	3/13/95 15:45	3.00E+04	4.93E-45	9.86E-45						
MW7-8-17	MW-3 AB	8.10	12:30	0.5208	9600	3.00E+05	3.5778	3/13/95 17:53	3/13/95 23:18	3/14/95 6:41	3/14/95 11:52	3.00E+04	7.47E-59	1.49E-58						

TABLE 2-10 (Continued)

CALCULATED TIME-WEIGHTED MEAN GROUNDWATER ELEVATIONS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

CONFINED AQUIFER

Well No.	Well No.	Head in Well FEET (feet)		TIME (days)	Distance t Delaware River (feet)	Mean T/S confined (ft^2/day)	Time Lag (days)	3/10/95 4:02 TIME of Low Well	3/10/95 9:27 TIME of High Well	3/10/95 16:50 TIME of Low Well	3/10/95 22:01 TIME of High Well	Mean T/S confined (ft^2/day)	Stage Ratio /2 well rang	Stage Ratio full well range	Time initial days	Time final days	Time measured days	head initial feet MSL	head final feet MSL	head average feet MSL
MW1-21-173	DB-8	1.96		0.4389	295	8.00E+07	0.0642	3/10/95 5:34	3/10/95 10:59	3/10/95 18:22	3/10/95 23:33	3.00E+06	3.31E-01	6.63E-01	0.2323	0.4580	0.4389	1.353	2.018	1.685
MW6-17-109	FUA04D	1.26		0.4514	2040	8.00E+07	0.0466	3/10/95 5:09	3/10/95 10:34	3/10/95 17:57	3/10/95 23:08	3.00E+06	3.82E-01	7.63E-01	0.4403	0.7479	0.4514	1.288	0.524	0.906
MW6-18-113	FDP14D	1.92		0.4771	600	8.00E+07	0.0114	3/10/95 4:18	3/10/95 9:43	3/10/95 17:06	3/10/95 22:17	3.00E+06	3.37E+00	6.74E+00	0.4052	0.7128	0.4771	3.496	-3.244	3.370
MW5-24-80	TB-1D	9.11		0.5611	8700	8.00E+07	0.1986	3/10/95 8:47	3/10/95 14:12	3/10/95 21:36	3/11/95 2:46	3.00E+06	3.10E-05	6.20E-05	0.3668	0.5923	0.5611	9.110	9.110	9.110
MW5-30-77	TB-4D	8.99		0.5556	8100	8.00E+07	0.1849	3/10/95 8:28	3/10/95 13:53	3/10/95 21:16	3/11/95 2:27	3.00E+06	7.24E-05	1.45E-04	0.3529	0.5786	0.5556	8.990	8.990	8.990
MW5-36-82	FUB05D	9.00		0.5701	6400	8.00E+07	0.1461	3/10/95 7:32	3/10/95 12:57	3/10/95 20:20	3/11/95 1:31	3.00E+06	8.02E-04	1.60E-03	0.3141	0.5398	0.5701	8.998	9.000	8.999
MW4-29-132	PTP2D	2.77		0.4840	1600	8.00E+07	0.0365	3/10/95 4:54	3/10/95 10:19	3/10/95 17:42	3/10/95 22:53	3.00E+06	7.11E-01	1.42E+00	0.4303	0.7379	0.4840	3.019	1.596	2.307
MW4-31-132	PWD	2.78		0.4799	1420	8.00E+07	0.0257	3/10/95 4:39	3/10/95 10:04	3/10/95 17:27	3/10/95 22:38	3.00E+06	7.47E-01	1.49E+00	0.4196	0.7271	0.4799	3.073	1.579	2.326
MW4-27-103	FUA01D	2.82		0.4701	2230	8.00E+07	0.0509	3/10/95 5:15	3/10/95 10:40	3/10/95 18:03	3/10/95 23:14	3.00E+06	2.92E-01	5.84E-01	0.4448	0.7523	0.4701	2.868	2.286	2.577
MW4-21-101	FUA02D	2.80		0.4604	2220	8.00E+07	0.0507	3/10/95 5:14	3/10/95 10:39	3/10/95 18:02	3/10/95 23:13	3.00E+06	2.96E-01	5.92E-01	0.4444	0.7521	0.4604	2.631	2.039	2.335
MW4-15-119	88	2.85		0.4646	2270	8.00E+07	0.0564	3/10/95 5:23	3/10/95 10:48	3/10/95 18:11	3/10/95 23:22	3.00E+06	4.39E-01	8.77E-01	0.4502	0.7578	0.4646	2.891	2.014	2.452

DELAWARE RIVER TIDAL DATA

River at PHILA Time	Head	River at Fieldsboro Time (hrs:min)		River at Fieldsboro Time (days)	Head	River at Fieldsboro Period (days)	River at Fieldsboro Half Range
3/10/95 2:32	0.2	4:02	4:02	0.168	0.23	0.5333	3.48E+00
3/10/95 8:26	5.7	9:27	9:27	0.394	7.18	0.5236	3.42E+00
3/10/95 15:20	0.3	16:50	16:50	0.701	0.35		3.10E+00
3/10/95 21:00	5.2	22:01	22:01	0.917	6.55		

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 2-13

AQUIFER CHARACTERISTICS FROM SLUG TESTING

Well	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Storage
MW1-22-173	not determined	not determined	not determined
MW4-15-119, Test 1	90	4.5	$3x10^{-6}$
MW4-15-119, Test 2	95	4.5	$1x10^{-9}$

Source: BCM Engineers Inc. Project No. 00-5039-7023

TABLE 2-14

SLUG TEST EVALUATION OF SELECTED WELLS
U.S. STEEL FAIRLESS WORKS

February 1997

Well	Falling K (ft/d)	Rising K (ft/d)	means	Water-Bearing Zone
MW4-37-29	2.4	2.3	2.4	SHALLOW WATER TABLE
MW1-27-19	32.7	27.5	30.1	SHALLOW WATER TABLE
MW6-6-24	60.4	93.2	76.8	SHALLOW WATER TABLE
mean	36.4	35.3	35.8	SHALLOW WATER TABLE
MW2-4-77	90.2	96.2	93.2	DEEP WATER TABLE
MW6-29-73	95.0	84.6	89.8	DEEP WATER TABLE
MW1-28-74	47.7	50.0	48.8	DEEP WATER TABLE
mean	77.3	22.4	49.9	DEEP WATER TABLE
MW7-14-75	22.8	75.9	49.3	CONFINED AQUIFER

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 3-1
BORROW PITS

SWMU	Materials	Approx. Surface Area (acres)	Est. Qty. of Materials (cy)	Status
BP-1	Slag, Finishing Mill Treatment Plant sludge	117	547,000	Filled to grade; some open water
BP-2 North	Steel slag, slag fines, minimal general refuse (wood, bricks, tires)	35.7	145,000	Filled to grade
BP-2 South	Steel slag, minimal scrap metal and general refuse	58.9	237,000	Filled to grade
BP-3	Open hearth precipitator dust, electric furnace dust, blast furnace and sinter plant dust/sludges, general refuse	85.0	1,330,000	Segregated cells filled to grade; some open water
BP-4	Steel slag, general refuse, scrap metal, ties	112	363,000	Filled to grade
BP-5A	Steel slag, coal fines, general refuse, scrap metal	2.7	9,000	50% filled to grade
BP-8	Steel slag	14.0	91,000	Filled to grade
BP-8A	Tar sludge, coke breeze, general refuse	1.2	5,000	Some tar removed; some open water
BP-8B	Steel slag, coal fines, general refuse	5.2	21,000	5.5 acres filled to grade
BP-9	Steel slag, Ladle House wastes	11.3	73,000	Partially filled to grade
BP-10	Steel slag	2.8	22,000	Filled to grade
BP-10A	Steel slag	2.4	19,000	Filled to grade
BP-10B	Steel slag, wastewater overflow	0.5	2,000	Some open water
BP-13	Steel slag, Ladle House waste, paint waste, tar decanter sludge	8.5	49,000	Filled to grade
BP-13A	Coke Plant wastewater overflows, spent dephenolizer caustic	2.1	13,000	Filled to grade

TABLE 3-1
BORROW PITS (Continued)

SWMU	Materials	Approx. Surface Area (acres)	Est. Qty. of Materials (cy)	Status
BP-14 North	Steel slag			Filled to grade
BP-14 South	Steel slag, coke plant wastewater, ammonia still lime sludge, dephenolizer spent caustic	7.9	55,000	Partially filled to grade
BP-15	Iron slag	12.0	78,000	Filled to grade
BP-17	Steel slag, minimal general refuse	7.3	33,000	11 acres filled to grade
BP-19	Steel slag	2.9	19,000	Filled to grade
BP-20	Slag, tar decanter sludge	10.3	25,000	RCRA closure
BP-21	Iron slag	30.5	100,000	Wheelabrator property
BP-23, 24 and 25	Steel slag	35.3	114,000	Filled to grade
BP-26	Steel slag	2.7	17,000	Filled to grade
BP-27	Steel slag, minimal rail car and track maintenance waste	2.7	11,000	Some open water
BP-29	Steel slag	1.4	9,000	Filled to grade
BP-30	Steel slag, dredge spoils	0.7	5,000	Filled to grade
BP-31	Iron slag	14.4	46,000	Wheelabrator property
BP-31A	Iron slag	21.7	69,000	Wheelabrator property
BP-32	Steel slag, general refuse, dried oil sludge, scrap metal	16.1	64,000	Filled to grade
BP-33	Slag (limited)	1.6	38,000	Unused

TABLE 3-1
BORROW PITS (Continued)

SWMU	Materials	Approx. Surface Area (acres)	Est. Qty. of Materials (cy)	Status
BP-35	Terminal Treatment Plant sludge	2.9	23,000	Interim Measure Workplan submitted
BP-35A	Terminal Treatment Plant sludge	1.7	12,000	
BP-35B	Terminal Treatment Plant sludge	2.8	45,000	
BP-35C	Terminal Treatment Plant sludge	0.8	13,000	
BP-37	Steel slag, dredge spoils	31.6	148,000	Filled to grade
BP-38	Steel slag	57.7	282,000	Filled to grade
BP-40	Steel slag, acid rinse water, borax	4.0	16,000	3.5 acres filled to grade
NT-1	Slag	12.1	292,000	
NT-2	Steel slag, Pipe Mill debris, brick	11.7	76,000	Permitted for slag disposal
NT-3	Finishing Mill Treatment Plant sludge, lime stabilized spent pickle liquor, scale pit wastes	32.6	91,000	Partially filled to grade
NT-4	Steel slag, oil skimmings, brick	17.6	115,000	Filled to grade
NT-A	Slag, Pipe Mill scale pit effluent, minimal general refuse	4.4	29,000	4.8 acres filled to grade
NT-B	Brick, Pipe Mill waste	4.0	25,000	Filled to grade

Source: Description of Current Conditions (BCM, 1994)

TABLE 4-2

IRON AND STEEL SLAG TOTAL AND LEACHATE SAMPLE RESULTS
U.S. STEEL FAIRLESS WORK
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Sample Description: Sample Number: Sample Date:		SE-BP-21 504805 3/9/95	SE-BP-31 501926 1/24/95	SE-BP-31-A 501928 1/24/95	SE-BP-23-5 501930 1/24/95	SE-BP-23-5-D 501932 1/24/95	SE-NT-1 501934 1/24/95	SE-NT-2 501936 1/24/95
Parameters (mg/kg):								
Reduction/Oxidation Potential	mV	420	430	342	353	353	280	348
Cyanide		0.929	ND	0.109	ND	ND	ND	0.159
Sulfides		119	57.8	137	ND	ND	ND	ND
Silver		ND	ND	3.52	2.16	2.97	3.99	0.654
Arsenic		4.38	4.43	0.620	1.32	1.40	1.02	3.18
Barium		246	35.2	130	59.4	55.7	32.2	19.5
Beryllium		4.60	0.526	1.02	0.426	0.302	ND	ND
Cadmium		ND	4.06	22.3	21.1	23.8	24.1	8.89
Cobalt		3.00	7.54	11	10.8	18.1	16.1	5.67
Chromium		16.5	33.4	871	541	762	1149	65.6
Copper		ND	9.86	3.93	9.41	11.7	5.68	33.3
Mercury		ND	ND	ND	ND	ND	ND	ND
Nickel		2.54	12.4	4.55	8.21	10.1	32.5	14.8
Lead		2.97	25.6	14.0	21.6	21.7	42.1	41.5
Antimony		ND	ND	ND	ND	ND	ND	ND
Selenium		1.99	0.126	ND	ND	ND	ND	ND
Tin		ND	ND	ND	ND	ND	ND	ND
Thallium		ND	ND	ND	ND	ND	ND	ND
Vanadium		10.8	13.3	146	97.5	118	409	24.9
Zinc		8.71	45.9	43.3	107	94.7	110	180

ND compound not detected above laboratory method detection limit
mV milli volts
mg/kg milligrams per kilogram

TABLE 4-2 (CONTINUED)

IRON AND STEEL SLAG TOTAL AND LEACHATE SAMPLE RESULTS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Sample Description: / Sample Number: / Sample Date:		SE-BP-21 504805 3/9/95	SE-BP-31 501927 1/24/95	SE-BP-31-A 501929 1/24/95	SE-BP-23-5 501931 1/24/95	SE-BP-23-5-D 501933 1/24/95	SE-NT-1 501935 1/24/95	SE-NT-2 501937 1/24/95
TCLP Parameters (mg/l):	TCLP CRITERIA							
Silver	5.0	ND	ND	ND	ND	ND	ND	ND
Arsenic	5.0	ND	ND	ND	ND	ND	ND	ND
Barium	100.0	0.415	0.711	0.39	0.416	0.293	0.172	0.370
Cadmium	1.0	ND	ND	ND	ND	ND	ND	0.008
Chromium	5.0	ND	0.008	ND	ND	ND	0.007	0.015
Mercury	0.2	ND	ND	ND	ND	ND	ND	ND
Lead	5.0	ND	ND	ND	ND	ND	ND	ND
Selenium	1.0	ND	ND	ND	ND	ND	ND	0.314

ND compound not detected above laboratory method detection limit
mV milli volts
mg/l milligrams per liter
TCLP Toxicity Characteristic Leaching Procedure

TABLE 4-3

SLAG EVALUATION GROUNDWATER MONITORING WELLS

Well Designation	Slag Type
MW6-2-27	Iron Slag
MW6-5-28	Iron Slag
MW7-4-26	Iron Slag
MW6-4-29	Iron Slag
MW6-8-28	Iron Slag
MW5-1-26	Steel Slag
MW5-2-24	Steel Slag
MW 2	Steel Slag
MW 4	Steel Slag
MW 6	Steel Slag
MW7-12-25	Background
MW9-1-20	Background

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 4-4
SLAG EVALUATION GROUNDWATER SAMPLE RESULS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

EEL SLAG

Sample Designation:			MW6-2-27	MW6-2-27	MW6-4-29	MW6-4-29	MW6-5-28	MW6-5-2
Sample Date:			4/12/95	4/12/95	4/12/95	4/12/95	4/12/95	4/12/95
Sample Number (unfiltered):			507575	--	507577	--	507579	--
Sample Number (filtered):			--	507576	--	507578	--	507580
		MCL*/SMCL**						
Total alkalinity	mg/l		128	NT	274	NT	386	NT
P alkalinity	mg/l		0	NT	0	NT	0	NT
Bicarbonate alkalinity	mg/l		128	NT	274	NT	386	NT
Carbonate alkalinity	mg/l		0	NT	0	NT	0	NT
Hydroxide alkalinity	mg/l		0	NT	0	NT	0	NT
Free Carbon Dioxide	mg/l		52.2	NT	74.0	NT	287	NT
Chloride	mg/l	250**	26.1	NT	5.60	NT	33.7	NT
Cyanide	mg/l	0.2*	< 0.002	NT	0.022	NT	< 0.002	NT
Fluoride	mg/l	4*	0.104	NT	0.109	NT	< 0.1	NT
Nitrate as Nitrogen	mg/l	10*	0.230	NT	< 0.05	NT	3.07	NT
Sulfide	mg/l		< 1	NT	< 1	NT	< 1	NT
Metals								
Silver	mg/l	0.1**	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/l	0.05*	< 0.001	< 0.001	0.004	0.003	< 0.001	< 0.001
Barium	mg/l	2*	0.048	0.084	0.238	0.322	0.066	0.104
Beryllium	mg/l	0.004*	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Calcium	mg/l		34.9	34.4	53.8	54.7	48.3	46.8
Cadmium	mg/l	0.005*	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Cobalt	mg/l		< 0.005	< 0.005	0.006	< 0.005	0.007	0.007
Chromium	mg/l	0.1*	0.0042	< 0.0025	0.0053	< 0.0025	< 0.0025	< 0.0025
Trivalent Chromium	mg/l		0.0042	NT	0.0053	NT	< 0.0025	NT
Hexavalent Chromium	mg/l		< 0.005	NT	< 0.005	NT	< 0.005	NT
Copper	mg/l	1.3 AL	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Iron	mg/l	0.3**	***2.49***	< 0.025	***31.6***	***28***	0.214	< 0.025
Mercury	mg/l	0.002*	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	mg/l		8.52	8.12	3.97	3.92	8.08	7.88
Magnesium	mg/l		15.3	14.8	21.8	22.4	16.7	16.3
Manganese	mg/l	0.05**	***4.98***	***4.62***	***3.31***	***3.2***	0.042	0.002
Sodium	mg/l		18.1	18.3	3.62	4.39	17.3	18.1
Nickel	mg/l	0.1*	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Lead	mg/l	0.015 AL	0.001	< 0.001	***0.023***	< 0.001	< 0.001	< 0.001
Antimony	mg/l	0.006*	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Selenium	mg/l	0.05*	<0.001	< 0.001	<0.001	< 0.001	< 0.001	< 0.001
Tin	mg/l		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Thallium	mg/l	0.002*	<0.001	< 0.001	<0.001	< 0.001	< 0.001	< 0.001
Vanadium	mg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	5**	0.143	0.162	0.184	< 0.006	< 0.006	0.049
Field Parameters								
Dissolved Oxygen	mg/l		1.0	NT	2.8	NT	1.4	NT
pH	std. units	6.5 - 8.5**	***6.17***	NT	6.51	NT	***6.18***	NT
Specific Conductance	umhos		427	NT	522	NT	451	NT
Temperature	deg. C		12.8	NT	16.3	NT	12.4	NT

*National Primary Drinking Water Regulations Maximum Contaminant Level (MCL)

**National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

NT = Not Tested AL = Action Level

TABLE 4-4 (Continued)
SLAG EVALUATION GROUNDWATER SAMPLE RESULS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

STEEL SLAG

Sample Designation:			MW6-8-28	MW6-8-28	MW7-4-26	MW7-4-26	Rinse Blk	Rinse Blk
Sample Date:			4/12/95	4/12/95	4/12/95	4/12/95	4/12/95	4/12/95
Sample Number (unfiltered):			507581	- -	507583	- -	507584	- -
Sample Number (filtered):			- -	507582	- -	507591	- -	507592
		MCL*/SMCL**						
Total alkalinity	mg/l		62.0	NT	120	NT	1	NT
P alkalinity	mg/l		0	NT	0	NT	0	NT
Bicarbonate alkalinity	mg/l		62.0	NT	120	NT	1	NT
Carbonate alkalinity	mg/l		0	NT	0	NT	0	NT
Hydroxide alkalinity	mg/l		0	NT	0	NT	0	NT
Free Carbon Dioxide	mg/l		33.4	NT	55.0	NT	33.2	NT
Chloride	mg/l	**250****	34.9	NT	58.8	NT	< 1.0	NT
Cyanide	mg/l	**0.2***	< 0.002	NT	< 0.002	NT	< 0.002	NT
Fluoride	mg/l	**4***	0.102	NT	< 0.1	NT	< 0.1	NT
Nitrate as Nitrogen	mg/l	**10***	0.621	NT	4.48	NT	< 0.05	NT
Sulfide	mg/l		< 1	NT	< 1	NT	< 1	NT
Metals								
Silver	mg/l	**0.1****	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/l	**0.05***	< 0.001	< 0.001	0.006	< 0.001	< 0.001	< 0.001
Barium	mg/l	**2***	0.057	0.107	0.099	0.099	< 0.01	< 0.01
Beryllium	mg/l	**0.004***	< 0.0005	< 0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005
Calcium	mg/l		41.6	37.6	60.2	64.9	< 0.022	0.054
Cadmium	mg/l	**0.005***	< 0.0025	< 0.0025	< 0.005	< 0.0025	< 0.0025	< 0.0025
Cobalt	mg/l		0.005	< 0.005	0.008	< 0.005	< 0.005	< 0.005
Chromium	mg/l	**0.1***	< 0.0025	< 0.0025	0.0092	< 0.0025	< 0.005	< 0.005
Trivalent Chromium	mg/l		< 0.0025	NT	0.0092	NT	< 0.005	NT
Hexavalent Chromium	mg/l		< 0.005	NT	< 0.005	NT	< 0.005	NT
Copper	mg/l	**1.3 AL**	< 0.005	< 0.005	0.014	< 0.005	< 0.005	< 0.005
Iron	mg/l	**0.3****	0.298	< 0.025	***14.1***	< 0.025	< 0.025	< 0.025
Mercury	mg/l	**0.002***	0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	mg/l		14.4	12.5	14.0	14.2	< 0.2	< 0.2
Magnesium	mg/l		12.9	11.5	7.68	13.8	< 0.02	< 0.02
Manganese	mg/l	**0.05****	***0.189***	***0.064***	***0.604***	***0.156***	< 0.002	< 0.002
Sodium	mg/l		16.7	15.7	19.6	22.1	< 0.2	0.804
Nickel	mg/l	**0.1***	< 0.01	< 0.01	0.013	< 0.01	< 0.01	< 0.01
Lead	mg/l	**0.015 AL**	< 0.001	< 0.001	0.006	< 0.001	< 0.001	< 0.001
Antimony	mg/l	**0.006***	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Selenium	mg/l	**0.05***	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Tin	mg/l		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Thallium	mg/l	**0.002***	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vanadium	mg/l		< 0.01	< 0.01	0.012	< 0.01	< 0.01	< 0.01
Zinc	mg/l	**5****	0.093	0.110	0.043	0.071	< 0.006	0.007
Field Parameters								
Dissolved Oxygen	mg/l		1	NT	1.9	NT	NT	NT
pH	std. units	**6.5 - 8.5****	***6.2***	NT	***6.32***	NT	NT	NT
Specific Conductance	umhos		388	NT	552	NT	NT	NT
Temperature	deg. C		14.6	NT	11.5	NT	NT	NT

* National Primary Drinking Water Regulations Maximum Contaminant Level (MCL)

** National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

' = Not Tested   AL = Action Level

TABLE 4-4 (Continued)
SLAG EVALUATION GROUNDWATER SAMPLE RESULS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

ON SLAG

Sample Designation:			MW 2	MW 2	MW 4	MW 4	MW 6	MW 6
Sample Date:			4/13/95	4/13/95	4/13/95	4/13/95	4/13/95	4/13/95
Sample Number (unfiltered):			507672	--	507674	--	507676	--
Sample Number (filtered):			--	507673	--	507675	--	507677
		MCL*/SMCL**						
Total alkalinity	mg/l		20.0	NT	144	NT	214	NT
P alkalinity	mg/l		0	NT	0	NT	0	NT
Bicarbonate alkalinity	mg/l		20.0	NT	144	NT	214	NT
Carbonate alkalinity	mg/l		0	NT	0	NT	0	NT
Hydroxide alkalinity	mg/l		0	NT	0	NT	0	NT
Free Carbon Dioxide	mg/l		8.95	NT	2.09	NT	83.5	NT
Chloride	mg/l	**250****	4.44	NT	7.63	NT	13.2	NT
Cyanide	mg/l	**0.2***	< 0.002	NT	< 0.002	NT	< 0.002	NT
Fluoride	mg/l	**4***	0.133	NT	1.00	NT	0.139	NT
Nitrate as Nitrogen	mg/l	**10***	0.287	NT	0.744	NT	< 0.05	NT
Sulfide	mg/l		< 1	NT	< 1	NT	< 1	NT
Metals								
Silver	mg/l	**0.1****	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/l	**0.05***	0.002	0.001	0.004	< 0.001	0.006	0.005
Barium	mg/l	**2***	0.026	0.012	0.086	0.034	0.054	0.119
Beryllium	mg/l	**0.004***	< 0.0005	< 0.0005	0.0007	< 0.0005	< 0.0005	< 0.0005
Calcium	mg/l		11.4	11.6	147	127	76.5	76.3
Cadmium	mg/l	**0.005***	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Cobalt	mg/l		< 0.005	< 0.005	0.009	< 0.005	< 0.005	< 0.005
Chromium	mg/l	0.1*	< 0.0025	< 0.0025	0.016	0.003	< 0.0025	< 0.0025
Trivalent Chromium	mg/l		< 0.0025	NT	0.016	NT	< 0.0025	NT
Hexavalent Chromium	mg/l		< 0.005	NT	< 0.005	NT	< 0.05	NT
Copper	mg/l	1.3 AL	< 0.005	< 0.005	0.019	< 0.005	< 0.005	< 0.005
Iron	mg/l	**0.3****	***2.26***	0.032	***8.12***	< 0.025	***2.89***	***2.49***
Mercury	mg/l	**0.002***	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	mg/l		1.32	1.18	12.2	22.8	4.21	4.31
Magnesium	mg/l		4.27	4.16	43.7	30.7	21.0	21.8
Manganese	mg/l	**0.05****	***0.147***	< 0.002	***0.914***	0.022	***0.439***	***0.632***
Sodium	mg/l		2.69	2.80	4.65	5.69	9.79	11.2
Nickel	mg/l	**0.1***	< 0.01	< 0.01	0.012	< 0.01	< 0.01	< 0.01
Lead	mg/l	**0.015 AL**	0.004	< 0.001	***0.025***	< 0.001	< 0.001	< 0.001
Antimony	mg/l	**0.006***	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Selenium	mg/l	**0.05***	< 0.001	< 0.001	0.003	0.005	0.003	< 0.001
Tin	mg/l		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Thallium	mg/l	**0.002***	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vanadium	mg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	**5****	0.088	0.048	0.188	0.008	0.016	0.078
Field Parameters								
Dissolved Oxygen	mg/l		7.1	NT	2.3	NT	2.2	NT
pH	std. units	6.5 - 8.5**	***5.81***	NT	8.15	NT	***6.35***	NT
Specific Conductance	umhos		96	NT	717	NT	524	NT
Temperature	deg. C		8.9	NT	11.4	NT	8.1	NT

* National Primary Drinking Water Regulations Maximum Contaminant Level (MCL)

** National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

= Not Tested AL = Action Level

TABLE 4-4 (Continued)
SLAG EVALUATION GROUNDWATER SAMPLE RESULS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

ON SLAG

Sample Designation:			MW5-1-26	MW5-1-26	MW5-1-26D	MW5-1-26D	MW5-2-24	MW5-2-2
Sample Date:			4/13/95	4/13/95	4/13/95	4/13/95	4/13/95	4/13/95
Sample Number (unfiltered):			507678	--	507680	--	507682	--
Sample Number (filtered):			--	507679	--	507681	--	507683
		MCL*/SMCL**						
Total alkalinity	mg/l		166	NT	200	NT	244	NT
P alkalinity	mg/l		0	NT	0	NT	0	NT
Bicarbonate alkalinity	mg/l		166	NT	200	NT	244	NT
Carbonate alkalinity	mg/l		0	NT	0	NT	0	NT
Hydroxide alkalinity	mg/l		0	NT	0	NT	0	NT
Free Carbon Dioxide	mg/l		20.0	NT	11.0	NT	112	NT
Chloride	mg/l	250**	20.4	NT	19.5	NT	20.9	NT
Cyanide	mg/l	0.2*	< 0.002	NT	< 0.002	NT	< 0.002	NT
Fluoride	mg/l	4*	< 0.1	NT	< 0.1	NT	< 0.1	NT
Nitrate as Nitrogen	mg/l	10*	< 0.05	NT	< 0.05	NT	< 0.05	NT
Sulfide	mg/l		< 1	NT	< 1	NT	< 1	NT
Metals								
Silver	mg/l	0.1**	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/l	0.05*	< 0.001	0.001	< 0.001	< 0.001	0.049	0.018
Barium	mg/l	2*	0.031	0.022	< 0.024	0.028	0.138	0.203
Beryllium	mg/l	0.004*	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Calcium	mg/l		167	159	155	154	41.5	39.6
Cadmium	mg/l	0.005*	< 0.0025	< 0.0025	< 0.0025	0.004	< 0.0025	< 0.0025
Cobalt	mg/l		0.009	< 0.005	< 0.005	0.008	0.01	0.009
romium	mg/l	0.1*	0.007	0.003	< 0.0025	0.008	0.0028	< 0.0025
rivalent Chromium	mg/l		0.007	NT	< 0.0025	NT	0.0028	NT
Hexavalent Chromium	mg/l		< 0.005	NT	< 0.005	NT	< 0.005	NT
Copper	mg/l	1.3 AL	0.007	< 0.005	0.013	< 0.005	< 0.005	< 0.005
Iron	mg/l	0.3**	*1.94*	0.041	*1.52*	0.047	*39.6*	*21.0*
Mercury	mg/l	0.002*	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	mg/l		39	39.2	38.5	40	4.64	4.16
Magnesium	mg/l		32.9	31.5	33.5	33.8	17.7	16.8
Manganese	mg/l	0.05**	*1.25*	*0.951*	*1.16*	*0.930*	*21.5*	*20.3*
Sodium	mg/l		4.39	4.98	4.37	5.69	11.0	11.5
Nickel	mg/l	0.1*	0.012	< 0.01	< 0.01	0.012	< 0.01	< 0.01
Lead	mg/l	0.015 AL	0.003	< 0.001	0.005	< 0.001	0.004	< 0.001
Antimony	mg/l	0.006*	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Selenium	mg/l	0.05*	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Tin	mg/l		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Thallium	mg/l	0.002*	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vanadium	mg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	5**	0.014	0.016	0.016	0.039	< 0.006	0.042
Field Parameters								
Dissolved Oxygen	mg/l		1.0	NT	NT	NT	2.8	NT
pH	std. units	6.5 - 8.5**	6.95	NT	NT	NT	*6.27*	NT
Specific Conductance	umhos		932	NT	NT	NT	479	NT
Temperature	deg. C		11.9	NT	NT	NT	11.8	NT

* National Primary Drinking Water Regulations Maximum Contaminant Level (MCL)

** National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

= Not Tested AL = Action Level

TABLE 4-4 (Continued)
SLAG EVALUATION GROUNDWATER SAMPLE RESULS
U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

UPGRADIENT (USX INDUSTRIAL PARK)

Sample Designation:			MW7-12-25	MW7-12-25	MW9-1-20	MW9-1-20	Rinse Blk	Rinse Bl
Sample Date:			4/13/95	4/13/95	4/13/95	4/13/95	4/13/95	4/13/95
Sample Number (unfiltered):			507684	--	507686	--	507688	--
Sample Number (filtered):			--	507685	--	507687	--	507689
		MCL*/SMCL**						
Total alkalinity	mg/l		76.0	NT	58.0	NT	4	NT
P alkalinity	mg/l		0	NT	0	NT	0	NT
Bicarbonate alkalinity	mg/l		76.0	NT	58.0	NT	4	NT
Carbonate alkalinity	mg/l		0	NT	0	NT	0	NT
Hydroxide alkalinity	mg/l		0	NT	0	NT	0	NT
Free Carbon Dioxide	mg/l		11.5	NT	16.8	NT	8.19	NT
Chloride	mg/l	250**	26.4	NT	18.5	NT	< 1.0	NT
Cyanide	mg/l	0.2*	< 0.002	NT	< 0.002	NT	< 0.002	NT
Fluoride	mg/l	4*	< 0.1	NT	< 0.1	NT	< 0.1	NT
Nitrate as Nitrogen	mg/l	10*	0.969	NT	< 0.05	NT	< 0.05	NT
Sulfide	mg/l		< 1	NT	< 1	NT	< 1	NT
Metals								
Silver	mg/l	0.1**	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Arsenic	mg/l	0.05*	0.003	< 0.001	0.007	0.005	< 0.001	0.001
Barium	mg/l	2*	0.044	0.088	0.069	0.112	< 0.01	< 0.01
Beryllium	mg/l	0.004*	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Calcium	mg/l		19.5	18.7	19.0	19.4	0.057	0.065
Cadmium	mg/l	0.005*	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025	< 0.0025
Cobalt	mg/l		0.008	0.007	0.015	< 0.005	< 0.005	< 0.005
Chromium	mg/l	0.1*	***0.368***	***0.323***	0.005	< 0.0025	< 0.005	< 0.0025
Trivalent Chromium	mg/l		***0.368***	NT	0.005	NT	< 0.005	NT
Hexavalent Chromium	mg/l		< 0.005	NT	< 0.005	NT	< 0.005	NT
Copper	mg/l	1.3 AL	0.014	< 0.005	0.014	< 0.005	< 0.005	< 0.005
Iron	mg/l	0.3**	***1.62***	< 0.025	***6.45***	***1.76***	< 0.025	< 0.025
Mercury	mg/l	0.002*	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Potassium	mg/l		4.9	3.31	7.98	4.42	< 0.2	< 0.2
Magnesium	mg/l		6.68	6.49	6.94	6.60	< 0.02	< 0.02
Manganese	mg/l	0.05**	***0.142***	***0.087***	***3.04***	***3.30***	< 0.002	< 0.002
Sodium	mg/l		12.4	14.6	6.24	8.12	< 0.2	< 0.2
Nickel	mg/l	0.1*	***0.12***	< 0.01	0.02	< 0.01	< 0.1	< 0.1
Lead	mg/l	0.015 AL	0.003	< 0.001	0.005	< 0.001	< 0.001	< 0.001
Antimony	mg/l	0.006*	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Selenium	mg/l	0.05*	< 0.001	< 0.001	0.003	< 0.001	0.006	< 0.001
Tin	mg/l		< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Thallium	mg/l	0.002*	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001
Vanadium	mg/l		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zinc	mg/l	5**	0.033	0.073	0.071	0.027	< 0.006	< 0.006
Field Parameters								
Dissolved Oxygen	mg/l		7.9	NT	1.8	NT	NT	NT
pH	std. units	6.5 - 8.5**	***6.17***	NT	***6.47***	NT	NT	NT
Specific Conductance	umhos		221	NT	218	NT	NT	NT
Temperature	deg. C		12.4	NT	10.6	NT	NT	NT

* National Primary Drinking Water Regulations Maximum Contaminant Level (MCL)

** National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

NT = Not Tested   AL = Action Level

TABLE 4-5

SUMMARY OF METALS EXCEEDING DRINKING WATER STANDARDS IN SLAG EVALUATION GROUNDWATER SAMPLES

Sample Location	Sample Type	Number of Samples Above MCL/SMCL	Concentration Range in All Samples (mg/l)
Steel Slag	Unfiltered (total)	Fe (3 of 5) Mn (4 of 5) Pb (1 of 5)	Iron: 0.214 to 31.6 Manganese: 0.042 to 4.98 Lead: 0.023
Steel Slag	**Filtered (dissolved)**	**Fe (1 of 5)** **Mn (4 of 5)**	**Iron: 28.0** **Manganese: 0.002 to 4.62**
Iron Slag	Unfiltered (total)	Fe (6 of 6) Mn (6 of 6) Pb (1 of 5)	Iron: 1.52 to 39.6 Manganese: 0.147 to 21.5 Lead: 0.025
Iron Slag	**Filtered (dissolved)**	**Fe (2 of 6)** **Mn (4 of 6)**	**Iron: 0.032 to 21.0** **Manganese: 0.22 to 20.3**
Upgradient	Unfiltered (total)	Fe (2 of 2) Mn (2 of 2) Cr (1 of 2) Ni (1 of 2)	Iron: 1.62 to 6.45 Manganese:0.142 to 3.04 Chromium: 0.368 Nickel: 0.12
Upgradient	**Filtered (dissolved)**	**Fe (1 of 2)** **Mn (2 of 2)** **Cr (1 of 2)**	**Iron: 1.76** **Manganese:0.087 to 3.30** **Chromium: 0.323**

Fe - Iron
Mn - Manganese
Pb - Lead
Cr - Chromium
Ni - Nickel

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 4-6

CONCENTRATIONS OF IRON AND MANGANESE IDENTIFIED IN GROUNDWATER SAMPLES COLLECTED AT FAIRLESS WORKS - CIRCA 1955

U.S. STEEL FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA
PHASE 1 RFI

Sample Designation:			Well #1	Well #1	Well #2	Well #3	Well #6	Well #7
Sample Date:			3/4/55	4/1/55	3/8/55	3/8/55	3/26/55	3/31/55
		SMCL*						
Iron (total)	mg/l	**0.3***	nt	7.8	3	10.4	36.4	4.8
Iron (dissolved)	mg/l	**0.3***	2.0	4.2	0.2	2.3	0.1	0.1
Manganese (total)	mg/l	**0.05***	nt	0.2	nt	nt	2.1	1.9
Manganese (dissolved)	mg/l	**0.05***	0.2	nt	0	0.2	0.1	nt

Sample Designation:			Wel l#8	Well #9	Well A	Well A	Well A	Well A
Sample Date:			4/5/55	4/7/55	2/9/55	2/10/55	2/17/55	2/24/55
		SMCL*						
Iron (total)	mg/l	**0.3***	1.3	15.7	2.34	1.4	2.4	3.34
Iron (dissolved)	mg/l	**0.3***	0.1	nt	nt	nt	nt	nt
Manganese (total)	mg/l	**0.05***	0	7.5	1.6	1.45	1.2	1.1
Manganese (dissolved)	mg/l	**0.05***	nt	nt	nt	nt	nt	nt

Sample Designation:			Well B	Well B	Well B	Well C	Well C	Well C
Sample Date:			1/19/55	1/20/55	1/22/55	3/22/55	4/11/55	4/13/55
		SMCL*						
Iron (total)	mg/l	**0.3***	7.45	5.87	5.62	19.4	13.6	21.2
Iron (dissolved)	mg/l	**0.3***	nt	nt	nt	nt	nt	nt
Manganese (total)	mg/l	**0.05***	1.8	2.4	1.7	1.9	1.9	1.9
Manganese (dissolved)	mg/l	**0.05***	nt	nt	nt	nt	nt	nt

SOURCE: U.S. Steel Corp.

* National Primary Drinking Water Regulations Secondary Maximum Contaminant Level (SMCL)

nt = Not Tested

TABLE 6-1

PENNSYLVANIA AND NEW JERSEY WATER SUPPLY WELLS PROXIMATE(1) TO FAIRLESS WORKS

Well Owner	Address	Use	Depth (ft)	Aquifer(2)	Yield or Capacity (GPM)
Pennsylvania					
Kohler Air Products	Falls Township	I	47	W	170
Fairless Credit Union	Falls Township	D	---	---	---
New Jersey					
North American Marine Salvage	Bordentown	D	120	C	35
Peter Sukola	68 Delaware Ave. Bordentown	D	117	C	65
Matthew Rue	Main Street Fieldsboro	D	65	W	35
Ocean Spray Cranberries, Inc.	Park Street Bordentown, PA	I	267	C	300
Stepan Chemical Co.	Clark St. & Broadway Fieldsboro	I	185	C	100

(1) Domestic (D) wells within one-half mile and larger capacity Municipal (M) or Industrial (I) wells within one mile
(2) Aquifer: W = Water Table, C = Confined Aquifer

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 6-2

PERIMETER GROUNDWATER MONITORING WELL NETWORK

Well Destination	General Location	Aquifer
MW5-41-19	Upgradient	Shallow Water Table
MW7-4-26 (42)	Biles Creek	Shallow Water Table
MW7-5-28 (44)	Biles Creek	Shallow Water Table
MW6-5-28 (39)	Biles Creek	Shallow Water Table
MW6-2-27 (38)	Biles Creek	Shallow Water Table
MW6-29-73	Biles Creek	Deep Water Table
MW6-6-24 (37)	Delaware River	Shallow Water Table
MW6-12-42 (FUP02)	Delaware River	Shallow Water Table
MW6-20-37 (FUP01R)	Delaware River	Shallow Water Table
MW4-14-36 (87)	Delaware River	Shallow Water Table
MW4-10-23 (65)	Delaware River	Shallow Water Table
MW4-30-63 (PWS)	Delaware River	Deep Water Table
MW4-15-119 (88)	Delaware River	Confined
MW1-22-173 (DB-8)	Delaware River	Confined
MW4-2-24 (30)	BP-1	Shallow Water Table
MW2-3-33 (61)	BP-1	Shallow Water Table
MW2-1-22 (50)	BP-1	Shallow Water Table
MW2-4-77	BP-1	Deep Water Table
MW1-15-29 (24A)	BP 35	Shallow Water Table
MW1-27-19	BP 35	Shallow Water Table
MW1-28-74	BP 35	Deep Water Table
MW1-26-27	TTP	Shallow Water Table
MW1-12-29 (20A)	Boat Slip	Shallow Water Table
MW1-25-22	Boat Slip	Shallow Water Table
MW1-24-23	Boat Slip	Shallow Water Table
MW1-23-47	Boat Slip	Deep Water Table
MW4-37-29	Near Well 44	Confined
MW4-11-33 (64)	FMTP	Shallow Water Table
MW3-2-27 (13)	BP13A	Shallow Water Table
MW5-18-26 (70)	BP-17	Shallow Water Table

Source: BCM Engineers Inc., Project Number 00-5039-7023

TABLE 6-3

GROUNDWATER SAMPLE PARAMETERS

Appendix IX Volatile Organic Compounds
Appendix IX Heated Purge and Trap Volatile Organics
Appendix IX Semivolatile Organic Compounds
Appendix IX Metals
Field pH
Field Temperature
Field Specific Conductance

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 6-4
GROUNDWATER MONITORING DATA SUMMARY
FILTERED AND UNFILTERED METALS

Filtered	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Antimony	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arsenic	–	–	–	–	9.8	1.3	9	3.3	7.4	–	46.9	2.2	–	–	–	–
Barium	109	58.6	21.2	21.3	56.4	128	146	203	118	226	565	134	199	83.1	204	96.3
Beryllium	–	–	–	–	–	–	–	12.6	–	–	–	–	–	–	–	–
Cadmium	1.1	0.54	0.59	0.8	0.37	0.75	–	7	0.32	0.59	–	–	0.6	–	0.46	0.63
Chromium	–	–	–	–	–	–	–	–	–	1.6	–	–	–	3.5	5.9	–
Cobalt	1.9	–	2.7	3.3	2.7	3	2.6	515	7	4.3	3.4	7.1	2.8	5.8	1.9	5.6
Copper	5.8	–	4	5.9	6.4	5.2	4.1	6.7	6.6	6.7	5	2.6	7	5.9	3	4.6
Lead	0.8	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mercury	–	0.22	–	0.21	–	–	–	–	–	–	–	–	–	–	–	–
Nickel	–	–	7.4	4	6.9	16.6	2.4	344	2.6	5.9	8.3	5.9	6.2	3.3	7	6.6
Selenium	2.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Silver	–	–	–	–	2	–	–	–	–	2.8	–	–	–	–	–	–
Thallium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vanadium	–	–	2.2	2.6	4.4	–	5.2	3.3	2.3	2.7	3.7	–	–	1.4	–	–
Zinc	120	–	–	–	10.4	131	63.6	1210	91.9	101	133	223	215	17.2	677	128
Tin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Unfiltered	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Antimony	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arsenic	2.3	12.9	–	–	39.9	29.3	14.9	8.3	7.7	6.7	60.8	3.5	2.1	–	2.2	1.9
Barium	72.3	491	31.9	28.3	367	50.8	96.8	98.1	29	224	598	43	59.6	65.1	72.8	33.7
Beryllium	–	5.3	–	–	4.5	–	–	15.6	–	2.4	–	–	–	–	–	–
Cadmium	0.43		0.40	0.32	1.20	1.40	–	9.10	0.60	0.37	–	–	0.82	–	1.20	0.97
Chromium	11.7	192	11.2	7.6	88.8	17.9	–	–	1.7	39.8	15	3.4	–	2.5	11.5	4.7
Cobalt	7.2	81.7	8.3	4.2	44.7	7	6.6	581	7.6	51.7	5.7	7.3	4.9	6.4	5.6	8.6
Copper	15.8	148	8.5	3.2	175	24.2	5.5	28.5	7	53.1	24.8	3.7	9.4	6.5	10.5	10.4
Lead	5.3	25.4	1.1	1.1	19	46.7	5.4	21.3	–	14.1	19.4	4.1	1.1	–	2.2	1.4
Mercury	0.52	0.35	0.23	0.27	0.22	–	0.48	–	–	–	0.32	–	–	–	–	–
Nickel	9.7	151	10	10.4	144	21.8	6.4	375	3.7	60.7	11.9	6.8	8.8	3.5	10.3	8.1
Selenium	2.7	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–
Silver	–	–	–	–	–	–	–	–	–	–	–	–	8.3	–	–	–
Thallium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vanadium	10.5	185	2.8	–	71.2	10	7.2	7.8	2.6	35.6	14.2	–	3.2	2.3	5.5	8.1
Zinc	6.1	473	–	–	420	132	39	1250	22.4	157	77.5	131	140	13.2	775	24.1
Tin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Filtered	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Antimony	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arsenic	3.4	–	–	–	1.5	–	–	–	–	19.4	–	–	–	–	20.2	–
Barium	114	192	94.6	182	238	48.2	129	94	29.3	166	16.1	145	152	54.3	214	28.4
Beryllium	–	–	0.21	–	2.6	–	–	–	–	–	–	–	–	0.63	–	–
Cadmium	–	0.57	0.85	–	3	0.82	1.1	1	0.42	0.99	1.2	0.92	0.68	1.7	–	0.45
Chromium	–	–	1.6	–	5	2.8	4	2.1	4.3	–	4.8	6.8	2.5	–	4	4.2
Cobalt	74.1	3.5	2.3	1.7	4	–	3.2	3.7	–	–	3.7	2	2.8	160	1.8	–
Copper	6	6.8	7.5	4.9	9.9	–	5.3	5.5	2.8	2.7	6.9	4	5.1	–	–	–
Lead	–	–	–	–	–	1	–	–	–	–	1	0.8	1.2	1.2	2.1	–
Mercury	–	–	–	–	–	–	–	–	–	–	0.23	–	–	–	–	–
Nickel	38.4	3.3	2.9	2.9	4.5	–	–	7.2	3.2	6.5	4.2	–	3.8	130	–	–
Selenium	–	–	–	–	–	2.8	–	–	–	–	–	5.2	5.3	–	–	–
Silver	–	–	2.8	–	2.4	–	2.2	–	4.1	3.3	3.3	2.9	–	2.2	4	–
Thallium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vanadium	2.2	2.7	2.3	–	4.1	–	2	2.4	–	2	1.7	2.7	4.4	–	–	–
Zinc	122	101	16.7	70.1	120	21.5	39.7	25.7	–	–	–	50	–	200	–	–
Tin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Unfiltered	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Antimony	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Arsenic	3.8	–	1.6	1.7	–	–	36.6	–	–	17.6	7.4	–	–	–	16	–
Barium	25.9	51	56.8	55	55.5	24.4	143	54.3	–	209	227	66.4	128	37.6	1060	15.4
Beryllium	–	–	–	–	3.3	–	–	–	–	–	4.6	–	–	1	6.1	–
Cadmium	0.47	–	0.80	–	4.00	0.32	–	0.35	0.40	0.48	–	1.20	0.35	0.96	0.72	0.89
Chromium		1.5	1.5	1.3	3.6	5.3	5.4	4.6	3.2	12	61.8	9.2	13.2	4.5	176	4.1
Cobalt	72.8	3	3.2	2.4	5	–	4.2	3.1	–	4.4	41.5	3.6	3.2	161	71.9	3
Copper	9.2	5.7	6.6	4.9	11.2	5.1	6	–	2.5	14.5	116	6.7	17.6	3.8	169	9
Lead	1.2	–	2.1	1.2	1	7.5	–	–	–	4.8	32.1	4.2	5.5	2.2	49	1.3
Mercury	–	–	–	–	–	–	–	0.27	0.25	–	0.23	–	–	–	0.46	–
Nickel	35.6	3.5	4.3	3.6	4.5	4	7.4	4.2	–	8.3	68.5	5.8	5.3	129	169	5.9
Selenium	–	–	–	–	–	–	–	–	–	–	–	6.4	8.4	–	–	–
Silver	–	–	–	–	16.6	–	2.1	3.3	–	–	–	2.2	3.2	1.8	2.8	3
Thallium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Vanadium	5.2	3	2.8	1.6	5.6	–	3.1	–	–	7.9	102	3.2	8.4	2	149	2.8
Zinc	44	20.8	17.4	12.4	14.1	–	–	–	8.9	9.2	249	–	–	200	526	–
Tin	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

All concentrations in ug/L

– Not Detected

TABLE 6-5
GROUNDWATER MONITORING DATA SUMMARY
VOLATILE AND SEMIVOLATILE COMPOUNDS DETECTED

	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Volatiles																
Methylene Chloride	3	3	2	3	3	2	4	2	5	4	2	4	3	4	4	5
Carbon Disulfide	–	–	–	–	–	–	–	–	–	–	–	–	6	4	–	–
1,1-Dichloroethene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1,1-Dichloroethane	–	–	–	–	–	–	–	3	–	–	–	–	1	–	2	–
1,2-Dichloroethene (total)	–	–	–	–	–	–	–	2	–	–	–	–	3	1	4	–
Chloroform	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
1,1,1-Trichloroethane	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
Trichloroethene	–	–	–	–	–	–	–	11	–	–	–	–	3	6	13	–
Benzene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tetrachloroethene	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2	–
Toluene	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Xylene (total)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Semivolatiles																
bis(2-Ethylhexyl)phthalate	4	–	–	–	–	–	2	–	1	1	–	2	–	–	–	–
Acenapthene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
o-Toluidine	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diethylphthalate	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–
Di-n-butylphthalate	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
phenol	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3&4 methylphenol	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
naphthalene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1,4-naphthoquinone	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Volatiles																
Methylene Chloride	4	3	4	4	5	2	2	2	2	3	2	3	3	2	2	2
Carbon Disulfide	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1,1-Dichloroethene	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1,1-Dichloroethane	–	4	–	–	–	–	–	–	–	25	–	–	–	–	–	–
1,2-Dichloroethene (total)	–	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chloroform	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1,1,1-Trichloroethane	–	2	–	–	–	–	–	–	–	–	–	9	–	–	–	–
Trichloroethene	–	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Benzene	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–
Tetrachloroethene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Toluene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Xylene (total)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Semivolatiles																
bis(2-Ethylhexyl)phthalate	2	–	–	–	–	–	–	–	–	–	–	1	–	3	–	–
Acenapthene	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
o-Toluidine	–	–	–	–	–	–	–	–	–	–	–	–	–	–	25	–
Diethylphthalate	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Di-n-butylphthalate	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
phenol	–	–	–	–	–	–	–	–	–	8	–	–	–	–	–	–
3&4 methylphenol	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
naphthalene	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1,4-naphthoquinone	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

All concentrations in ug/L.

– Not Detected

TABLE 6-7
FILTERED AND UNFILTERED METALS CONCENTRATIONS
EXCEEDING SUBPART S SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	Subpart S Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Filtered																	
Antimony	6																
Arsenic	50																
Barium	2000																
Beryllium	4								12.6								
Cadmium	5								7.0								
Chromium	100																
Cobalt	no std.																
Copper	1300																
Lead	15																
Mercury	2																
Nickel	100								344								
Selenium	50																
Silver	100																
Thallium	2																
Vanadium	no std.																
Zinc	5000																
Tin	no std.																
Unfiltered																	
Antimony	6																
Arsenic	50											60.8					
Barium	2000																
Beryllium	4		5.3						15.6								
Cadmium	5								9.10								
Chromium	100		192														
Cobalt	no std.																
Copper	1300																
Lead	15						46.7										
Mercury	2																
Nickel	100		151			144			375								
Selenium	50																
Silver	100																
Thallium	2																
Vanadium	no std.																
Zinc	5000																
Tin	no std.																

	Subpart S Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Filtered																	
Antimony	6																
Arsenic	50																
Barium	2000																
Beryllium	4																
Cadmium	5																
Chromium	100																
Cobalt	no std.																
Copper	1300																
Lead	15																
Mercury	2																
Nickel	100														130		
Selenium	50																
Silver	100																
Thallium	2																
Vanadium	no std.																
Zinc	5000																
Tin	no std.																
Unfiltered																	
Antimony	6																
Arsenic	50																
Barium	2000																
Beryllium	4															6.1	
Cadmium	5																
Chromium	100															176	
Cobalt	no std.																
Copper	1300																
Lead	15															49	
Mercury	2																
Nickel	100														129	169	
Selenium	50																
Silver	100																
Thallium	2																
Vanadium	no std.																
Zinc	5000																
Tin	no std.																

All concentrations in ug/L

TABLE 6-8

VOLATILE AND SEMIVOLATILE COMPOUND CONCENTRATIONS

EXCEEDING SUBPART S SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	Subpart S Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Volatiles																	
Methylene Chloride	5.0																
Carbon Disulfide	4000																
1,1-Dichloroethene	7																
1,1-Dichloroethane	no std.																
1,2-Dichloroethene (total)	no std.																
Chloroform	100																
1,1,1-Trichloroethane	200																
Trichloroethene	5.0								11						6	13	
Benzene	5.0																
Tetrachloroethene	5.0																
Toluene	1000																
Xylene (total)	10000																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	6																
Acenapthene	no std.																
o-Toluidine	no std.																
Diethylphthalate	no std.																
Di-n-butylphthalate	4000																
phenol	20000																
3&4 methylphenol	2000 each																
naphthalene	no std.																
1,4-naphthoquinone	no std.																

	Subpart S Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Volatiles																	
Methylene Chloride	5.0																
Carbon Disulfide	4000																
1,1-Dichloroethene	7																
1,1-Dichloroethane	no std.																
1,2-Dichloroethene (total)	no std.																
Chloroform	100																
1,1,1-Trichloroethane	200																
Trichloroethene	5.0		33														
Benzene	5.0																
Tetrachloroethene	5.0																
Toluene	1000																
Xylene (total)	10000																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	6																
Acenapthene	no std.																
o-Toluidine	no std.																
Diethylphthalate	no std.																
Di-n-butylphthalate	4000																
phenol	20000																
3&4 methylphenol	2000 each																
naphthalene	no std.																
1,4-naphthoquinone	no std.																

All concentrations in ug/L

TABLE 6-9
FILTERED AND UNFILTERED METALS CONCENTRATIONS
EXCEEDING RBC SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	EPA RBC Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Filtered																	
Antimony	15																
Arsenic	11											46.9					
Barium	2600																
Beryllium	0.016								12.6								
Cadmium	18																
Chromium	37000																
Cobalt	2200																
Copper	1500																
Lead	no std.																
Mercury	11																
Nickel	730																
Selenium	180																
Silver	180																
Thallium	no std.																
Vanadium	260																
Zinc	11000																
Tin	22000																
Unfiltered																	
Antimony	15																
Arsenic	11		12.9			39.9	29.3	14.9				60.8					
Barium	2600																
Beryllium	0.016		5.3						15.6								
Cadmium	18																
Chromium	37000																
Cobalt	2200																
Copper	1500																
Lead	no std.																
Mercury	11																
Nickel	730																
Selenium	180																
Silver	180																
Thallium	no std.																
Vanadium	260																
Zinc	11000																
Tin	22000																

	EPA RBC Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Filtered																	
Antimony	15																
Arsenic	11										19.4					20.2	
Barium	2600																
Beryllium	0.016			0.21		2.60									0.63		
Cadmium	18																
Chromium	37000																
Cobalt	2200																
Copper	1500																
Lead	no std.																
Mercury	11																
Nickel	730																
Selenium	180																
Silver	180																
Thallium	no std.																
Vanadium	260																
Zinc	11000																
Tin	22000																
Unfiltered																	
Antimony	15																
Arsenic	11							36.6			17.6					16	
Barium	2600																
Beryllium	0.016															6.1	
Cadmium	18																
Chromium	37000																
Cobalt	2200																
Copper	1500																
Lead	no std.																
Mercury	11																
Nickel	730																
Selenium	180																
Silver	180																
Thallium	no std.																
Vanadium	260																
Zinc	11000																
Tin	22000																

All concentrations in ug/L

TABLE 6-10
VOLATILE AND SEMIVOLATILE COMPOUND CONCENTRATIONS EXCEEDING RBC SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	EPA RBC Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Volatiles																	
Methylene Chloride	4.1									5							5
Carbon Disulfide	1000																
1,1-Dichloroethene	0.044																
1,1-Dichloroethane	810																
1,2-Dichloroethene (total)	55																
Chloroform	0.15				2												
1,1,1-Trichloroethane	790																
Trichloroethene	1.6								11					3	6	13	
Benzene	0.36																
Tetrachloroethene	1.1								2							2	
Toluene	750																
Xylene (total)	12000																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	4.8																
Acenapthene	2200																
o-Toluidine	no std.																
Diethylphthalate	29000																
Di-n-butylphthalate	3700																
phenol	22000																
3&4 methylphenol	1800/180																
naphthalene	1500																
1,4-naphthoquinone	no std.																

	EPA RBC Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Volatiles																	
Methylene Chloride	4.1					5											
Carbon Disulfide	1000																
1,1-Dichloroethene	0.044		3														
1,1-Dichloroethane	810																
1,2-Dichloroethene (total)	55																
Chloroform	0.15		4														
1,1,1-Trichloroethane	790																
Trichloroethene	1.6		33														
Benzene	0.36										3						
Tetrachloroethene	1.1																
Toluene	750																
Xylene (total)	12000																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	4.8																
Acenapthene	2200																
o-Toluidine	no std.																
Diethylphthalate	29000																
Di-n-butylphthalate	3700																
phenol	22000																
3&4 methylphenol	1800/180																
naphthalene	1500																
1,4-naphthoquinone	no std.																

All concentrations in ug/L

TABLE 6-11
FILTERED METALS CONCENTRATIONS
EXCEEDING DRBC SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	DRBC Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Aquatic Life																	
Antimony	no std.																
Arsenic	190																
Barium	no std.																
Beryllium	no std.																
Cadmium	1.61								7								
Chromium	130																
Cobalt	no std.																
Copper	17.29																
Lead	16																
Mercury	0.012																
Nickel	230								344								
Selenium	5																
Silver	8.72																
Thallium	no std.																
Vanadium	no std.																
Zinc	154								1210				223	215		677	
Tin	no std.																
Human Health																	
Antimony	no std.																
Arsenic	9.19					9.8						46.9					
Barium	no std.																
Beryllium	0.00767								12.6								
Cadmium	14.5																
Chromium	33000																
Cobalt	no std.																
Copper	no std.																
Lead	no std.																
Mercury	0.144																
Nickel	607																
Selenium	100																
Silver	175																
Thallium	1.70																
Vanadium	no std.																
Zinc	9110																
Tin	no std.																

	DRBC Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Aquatic Life																	
Antimony	no std.																
Arsenic	190																
Barium	no std.																
Beryllium	no std.																
Cadmium	1.61					3									1.7		
Chromium	130																
Cobalt	no std.																
Copper	17.29																
Lead	16																
Mercury	0.012																
Nickel	230																
Selenium	5												5.2	5.3			
Silver	8.72																
Thallium	no std.																
Vanadium	no std.																
Zinc	154														200		
Tin	no std.																
Human Health																	
Antimony	no std.																
Arsenic	9.19										19.4					20.2	
Barium	no std.																
Beryllium	0.00767			0.21		2.6									0.63		
Cadmium	14.5																
Chromium	33000																
Cobalt	no std.																
Copper	no std.																
Lead	no std.																
Mercury	0.144																
Nickel	607																
Selenium	100																
Silver	175																
Thallium	1.70																
Vanadium	no std.																
Zinc	9110																
Tin	no std.																

All concentrations in ug/L

TABLE 6-12
VOLATILE AND SEMIVOLATILE COMPOUND CONCENTRATIONS
EXCEEDING DRBC HUMAN HEALTH SCREENING CRITERIA AND BACKGROUND WELL CONCENTRATIONS

	DRBC Screening Criteria	1 MW1-25-22 3019108 12/19/96	2 MW1-26-27 3019106 12/19/96	3 MW1-28-74 3019104 12/19/96	4 MW1-28-74D 3019105 12/19/96	5 MW2-1-22 3007608 12/11/96	6 MW2-3-33 3007607 12/11/96	7 MW4-10-23 3006504 12/10/96	8 MW4-11-33 3007605 12/11/96	9 MW4-14-36 3007601 12/11/96	10 MW4-15-119 3007602 12/11/96 Confined Aquifer	11 MW4-2-24 3007606 12/11/96	12 MW4-30-63 3006505 12/10/96	13 MW6-2-27 3006502 12/10/96	14 MW6-5-28 3006404 12/9/96	15 MW6-6-24 3006503 12/10/96	16 MW6-12-42 3007604 12/11/96
Volatiles																	
Methylene Chloride	2090																
Carbon Disulfide	no std.																
1,1-Dichloroethene	0.0573																
1,1-Dichloroethane	no std.																
1,2-Dichloroethene (total)	no std.																
Chloroform	5.67																
1,1,1-Trichloroethane	no std.																
Trichloroethene	2.70								11					3	6	13	
Benzene	1.19																
Tetrachloroethene	0.8								2							2	
Toluene	6760																
Xylene (total)	no std.																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	1.76	4						2					2				
Acenapthene	1180																
o-Toluidine	no std.																
Diethylphthalate	22600																
Di-n-butylphthalate	no std.																
phenol	20900																
3&4 methylphenol	no std.																
naphthalene	no std.																
1,4-naphthoquinone	no std.																

	DRBC Screening Criteria	17 MW6-20-37 3007603 12/11/96	18 MW6-29-73 3006501 12/10/96	19 MW7-4-26 3006402 12/9/96	20 MW7-4-26D 3006403 12/9/96	21 MW7-5-28 3006401 12/9/96	22 MW1-12-29 3009103 12/12/96	23 MW1-15-29 3009101 12/12/96	24 MW1-22-173 3009102 12/12/96 Confined Aquifer	25 MW1-23-47 3016901 12/18/96	26 MW5-18-26 3016903 12/18/96	27 MW5-41-19 3019101 12/19/96 Background	28 MW1-24-23 3009104 12/12/96	29 MW1-27-19 3016906 12/18/96	30 MW2-4-77 3016905 12/18/96	31 MW3-2-27 3016902 12/18/96	32 MW4-37-29 3016904 12/18/96
Volatiles																	
Methylene Chloride	2090																
Carbon Disulfide	no std.																
1,1-Dichloroethene	0.0573		3														
1,1-Dichloroethane	no std.																
1,2-Dichloroethene (total)	no std.																
Chloroform	5.67																
1,1,1-Trichloroethane	no std.																
Trichloroethene	2.70		33														
Benzene	1.19										3						
Tetrachloroethene	0.8																
Toluene	6760																
Xylene (total)	no std.																
Semivolatiles																	
bis(2-Ethylhexyl)phthalate	1.76	2													3		
Acenapthene	1180																
o-Toluidine	no std.																
Diethylphthalate	22600																
Di-n-butylphthalate	no std.																
phenol	20900																
3&4 methylphenol	no std.																
naphthalene	no std.																
1,4-naphthoquinone	no std.																

All concentrations in ug/L.

TABLE 6-15

ANURANS EXPECTED TO INHABIT EACH OPEN WATER

Open Water	Spring Peeper	Pickerel Frog	Fowlers Toad	American Toad	Bullfrog	Green Frog	Gray Treefrog	Cricket Frog
BP-1	✓	✓			✓	✓	✓	
BP-1 Horseshoe Lagoon	✓		✓		✓	✓		
BP-3 North Pond	✓	✓	✓		✓	✓		✓
BP-3 South Pond	✓	✓	✓		✓	✓		✓
BP-3 North Pit	✓	✓	✓		✓	✓		✓
BP-3 North Central Pit	✓	✓	✓					✓
BP-3 South Central Pit	✓	✓			✓	✓		
BP-3 South Pit	✓	✓	✓		✓	✓		
BP-4	✓	✓	✓		✓	✓		
BP-5	✓		✓		✓	✓		
BP-5A	✓	✓	✓	✓	✓	✓		
BP-8A	✓	✓	✓		✓	✓		✓
BP-8B	✓	✓	✓		✓	✓		
BP-9	✓	✓	✓		✓	✓		✓
BP-10B					✓	✓		
BP-13A			✓		✓	✓		
BP-14 North	✓	✓	✓		✓	✓		
BP-14 South	✓		✓		✓	✓		
BP-17	✓	✓			✓	✓		
BP-21	✓		✓	✓	✓	✓	✓	
BP-27		✓	✓	✓	✓	✓	✓	
BP-28A				✓	✓	✓	✓	
BP-28B					✓	✓	✓	
BP-31	✓	✓		✓	✓	✓		
BP-31A USX	✓		✓	✓	✓	✓		
BP-31A Wheelabrator			✓		✓	✓		
BP-37 North	✓				✓	✓	✓	✓
BP-37 Central	✓							
BP-37 South	✓	✓	✓	✓		✓	✓	✓
BP-37 Isolated			✓					
BP-39	✓	✓	✓	✓	✓	✓	✓	✓
BP-40	✓	✓	✓	✓	✓	✓		✓
BP-40 West	✓		✓		✓	✓	✓	
NT-A Main	✓	✓	✓		✓	✓	✓	
NT-A South	✓		✓				✓	
NT-B North	✓		✓			✓		
NT-B South	✓		✓			✓		
NT-2	✓	✓	✓	✓	✓	✓		
NT-3 North			✓	✓	✓	✓		
NT-3 South			✓	✓	✓	✓	✓	
NT-4 East	✓		✓	✓			✓	

Source: BCM Engineers Inc., Project No. 00-5039-7023

TABLE 6-18

ANURANS IDENTIFIED IN EACH OPEN WATER

Open Water	Spring Peeper	Pickerel Frog	Fowlers Toad	American Toad	Bullfrog	Green Frog	Gray Treefrog	Cricket Frog
BP-1	✓	✓	NE		✓	✓	✓	
BP-1 Horseshoe Lagoon	✓	NE	✓	NE	✓	✓	NE	
BP-3 North Pond	✓	Absent	✓	NE	✓	✓	NE	✓
BP-3 South Pond	✓	✓	✓	NE	✓	✓	NE	✓
BP-3 North Pit	✓	✓	✓		✓	✓		Absent
BP-3 North Central Pit	✓	Absent	✓		NE		NE	✓
BP-3 South Central Pit	✓	Absent	NE		✓	✓		
BP-3 South Pit	✓	Absent	✓	NE	✓	✓	NE	
BP-4	Absent	✓	✓		✓	✓		
BP-5	Absent		✓		✓	✓		
BP-5A	Absent	Absent	✓	Absent	✓	Absent	NE	
BP-8A	✓	Absent	✓		✓	✓		Absent
BP-8B	✓	Absent	✓		✓	✓	NE	
BP-9	✓	✓	✓		✓	✓		Absent
BP-10B			NE		✓	✓		
BP-13A			✓	NE	✓	Absent		
BP-14 North	✓	Absent	Absent		✓	✓		
BP-14 South	Absent		✓		✓	✓		
BP-17	✓	Absent	NE		✓	✓		
BP-21	✓		Absent	Absent	✓	✓	Absent	
BP-27	NE	✓	✓	✓	✓	✓	Absent	
BP-28A	NE			Absent	✓	✓	Absent	
BP-28B	NE	NE			✓	✓	✓	
BP-31	✓	Absent		Absent	✓	✓		
BP-31A USX	✓		Absent	Absent	Absent	✓		
BP-31A Wheelabrator			✓		✓	✓		
BP-37 North	✓		NE		✓	✓	✓	✓
BP-37 Central	✓				NE	NE		
BP-37 South	✓	✓	✓	Absent	NE	✓	✓	✓
BP-37 Isolated			✓	NE		NE		
BP-39	✓	✓	✓	✓	✓	✓	✓	✓
BP-40	✓	✓	✓	✓	✓	✓		✓
BP-40 West	✓	NE	✓		✓	✓		NE
NT-A Main	✓	✓	✓	NE	✓	Absent	Absent	
NT-A South	✓		✓				✓	
NT-B North	✓		Absent		NE	✓	NE	NE
NT-B South	✓		✓		NE	✓	NE	
NT-2	✓	✓	✓	Absent	✓	✓		
NT-3 North		NE	✓	Absent	✓	✓		
NT-3 South	NE	NE	✓	✓	✓	✓	Absent	
NT-4 East	✓	NE	✓	✓			✓	

TABLE 6-19

SUMMARY OF MANN-WHITNEY U-TEST

Open Water	Spring Peeper			Pickerel Frog			Fowlers Toad			Bullfrog			Green Frog		
	U	Z	Prob<|Z|	U	Z	Prob<|Z|	U	Z	Prob<|Z|	U	Z	Prob<|Z|	U	Z	Prob<|Z|
BP-1	164	-0.2381	0.405	28	0.0	0.500				243	-0.6550	0.255	89	-0.3006	0.380
BP-1 Horseshoe Lagoon	22	-3.9337	**<0.001**				48	-0.8229	0.205	312.5	-0.0473	0.480	42	-1.6656	0.050
BP-3 North Pond	214.5	-0.1934	0.425				50.5	-2.4706	0.005[a]	278	-1.1350	0.13	96.5	-0.8431	0.200
BP-3 South Pond	164	-0.2393	0.405	21.5	-2.0134	0.020[a]	21.5	-1.8481	0.022[a]	305.5	-0.6575	0.255	62.5	-0.8314	0.205
BP-3 North Pit	153	-0.2412	0.405				33	-0.4561	0.325	224.5	-1.6194	0.055	30.5	-1.5348	0.060
BP-3 North Central Pit	86.3	-0.7313	0.230				23	-0.3070	0.380						
BP-3 South Central Pit	142	-0.2724	0.395							248	-1.1893	0.115	66	-0.1269	0.450
BP-3 South Pit	134	-0.5274	0.300				20.5	-1.5617	0.060	175	-0.5634	0.287	60.5	-0.4856	0.315
BP-4				17.5	-0.5092	0.305	31	-2.5945	0.005[a]	62.5	-2.4557	**0.007**	15	-1.9470	**0.026**
BP-5										10.5	-0.9444	0.170	48	-0.6011	0.275
BP-5A							18.5	-0.0679	0.475	82.5	-1.2895	0.100			
BP-8A	54	-2.4796	**0.007**				35	-0.7395	0.230	187	-0.7751	0.220	53	-0.4777	0.315
BP-8B	48	-2.6941	**0.004**				47	-0.0415	0.485	234	-0.0564	0.480	14.5	-1.8885	**0.030**
BP-9	76.5	-0.1198	0.450	0	-0.2211	0.415	28	-2.7305	0.003[a]	250	-0.0551	0.480			
BP-10B										153	-1.4173	0.080			
BP-13A							27	-0.3169	0.375	76	-2.0223	**0.022**			
BP-14 North	65	-0.8992	0.185										43.5	-0.4395	0.330
BP-14 South							135.5	-1.9982	**0.023**	96.5	-1.8577	**0.030**	16.5	-2.1988	**0.014**
BP-17	125	-0.9243	0.180							168.5	-0.4243	0.335	35.5	-1.6428	0.050
BP-21	52.5	-2.0707	**0.019**							127	0.4229	0.335	0	1.0	0.500
BP-27				17.5	-0.5092	0.305	23.5	-0.5380	0.295	280	-0.3779	0.355	54	-0.4033	0.345
BP-28A										204.5	-2.0569	0.020[a]	78.5	-0.3460	0.365
BP-28B										234	-0.7426	0.023[a]	85	-0.0271	0.490
BP-31	137	-2.2200	**0.013**							214	-0.5249	0.300	31.5	-1.4986	0.065
BP-31A USX	69	-3.3714	**<0.001**										36.5	-0.7611	0.223
BP-31A Wheelabrator							0	0.0	0.500	55.5	-2.2255	**0.013**			

TABLE 6-19

SUMMARY OF MANN-WHITNEY U-TEST

BP-37 North	260	-0.7030	0.241							146	-2.1174	0.017[a]	48.5	-0.7418	0.229
BP-37 Central	115	-2.6806	**0.004**												
BP-37 South	290	-0.1235	0.450	21	-0.8624	0.194	17	0.0177	0.442						
BP-37 Isolated							4.5	-1.8505	0.030[a]						
BP-39	260	-0.2027	0.420	10.5	-1.5492	0.060	16	-3.9873	<0.001[a]	264	-0.5606	0.290	71	-0.3140	0.375
BP-40	237.5	-0.1179	0.455	10.5	-2.1153	0.017[a]	21	-3.4258	<0.001[a]	213	-1.1843	0.120	60.5	-0.4681	0.320
BP-40 West	227	-0.6280	0.265				20	-1.9205	0.028[a]	268	-0.0415	0.485	62	-0.3680	0.355
NT-A Main	62.5	-2.6374	**0.004**	14	-1.7581	0.040[a]	21	-2.4471	**0.007**	173	-1.6045	0.055			
NT-A South	76	-1.8162	**0.035**				39	0.2564	0.400						
NT-B North	143	-0.2370	0.405										55.5	-0.1065	0.460
NT-B South	149	-0.0639	0.475				51.5	-0.0757	0.470				36	-1.2668	0.103
NT-2	50	-3.1040	**0.001**	28	0.0	0.500	93	-3.3252	<0.001[a]	119	-0.0398	0.484	90	-0.6961	0.245
NT-3 North							23.5	-0.5380	0.295	279	-0.5028	0.310			
NT-3 South							67.5	-1.2600	0.105	220	-1.2653	0.105	18.5	-2.4563	**0.007**
NT-4 East	62.5	-2.7192	**0.004**				0	-1.1180	0.130						

[a] - Activity index in open water is greater than reference sites

TABLE 6-20

WATER QUALITY OF ON SITE OPEN WATERS

Open Water	Temperature (°C)		Dissolved Oxygen (mg/l)		Mean Specific Conductance (μmhos)	Mean pH (Standard Units)
	Maximum	Minimum	Maximum	Minimum		
BP-1	30.0	18.5	9.4	4.9	204	6.5
BP-1 Horseshoe Lagoon	30.0	18.5	9.7	6.0	291	7.1
BP-3 North Pond	29.5	21.0	10.0	4.2	310	8.0
BP-3 South Pond	30.0	18.5	9.7	7.4	32	8.9
BP-3 North Pit	30.0	20.0	12.5	7.0	649	8.3
BP-3 North Central Pit	N/A	N/A	N/A	N/A	N/A	N/A
BP-3 South Central Pit	31.0	21.5	12.0	6.0	267	8.5
BP-3 South Pit	30.0	22.0	10.0	2.2	602	7.1
BP-4	27.0	20.0	8.6	5.0	191	9.4
BP-5	31.0	23.0	11.8	7.4	465	7.9
BP-5A	27.5	22.0	10.8	6.4	630	6.4
BP-8A	28.0	20.5	11.0	5.0	146	7.6
BP-8B	27.0	25.0	9.0	4.0	300	6.5
BP-9	30.0	17.0	10.8	6.0	217	8.6
BP-10B	27.0	25.0	9.0	4.0	300	6.5
BP-13A	29.0	17.5	9.9	5.2	188	6.9
BP-14 North	26.0	17.0	8.8	2.0	789	6.5
BP-14 South	29.0	20.0	12.0	4.7	300	7.9
BP-17	28.0	18.0	12.3	1.2	346	6.6
BP-21	27.5	18.0	8.4	1.3	188	6.7
BP-27	29.5	20.0	9.0	4.2	407	7.0
BP-28A	27.0	20.0	11.0	4.9	361	8.1
BP-28B	29.5	18.0	11.9	1.8	451	6.7
BP-31	29.0	17.5	11.0	2.6	332	7.5
BP-31A USX	27.0	15.5	4.4	0.1	409	7.4
BP-31A Wheelabrator	27.5	19.0	9.3	5.0	173	7.5
BP-37 North	28.0	17.0	9.2	5.0	295	6.7
BP-37 Central	26.5	16.0	4.1	0.1	245	6.1
BP-37 South	26.5	17.0	5.1	0.2	149	6.3
BP-37 Isolated	24.0	15.0	8.8	1.2	123	5.9
BP-39	33.5	18.5	9.0	0.6	554	5.8
BP-40	34.0	19.0	10.6	2.8	84	6.4
BP-40 West	27.0	15.0	9.6	2.5	404	6.5
NT-A Main	30.0	16.0	9.4	2.5	262	5.8
NT-A South	32.0	22.0	8.0	4.3	6	6.4
NT-B North	27.0	20.0	8.4	4.8	101	6.5
NT-B South	27.5	19.0	9.1	4.0	124	5.8
NT-2	28.0	15.0	9.8	4.4	429	6.7
NT-3 North	28.0	17.0	10.6	5.2	265	7.7
NT-3 South	28.5	16.0	9.4	5.0	257	7.6
NT-4 East	25.5	17.0	9.2	2.2	197	6.4

TABLE 6-21
SUMMARY OF ANURAN STUDY AND RANKING OF OPEN WATERS

Open Water	Spring Peeper	Pickerel Frog	Fowlers Toad	American Toad	Bullfrog	Green Frog	Gray Treefrog	Cricket Frog	PRIORITY	COMMENTS
BP-1	+	+	NE		+	+	+		3	
BP-1 Horseshoe Lagoon	-	NE	+	NE	+	-	NE		1	Spring Peeper, Green Frog<background
BP-3 North Pond	+	Absent	+	NE	+	+	NE	+	2	Pickerel Frog absent
BP-3 South Pond	+	+	+	NE	+	+	NE	+	3	
BP-3 North Pit	+	Absent	+		+	+		Absent	1	Pickerel Frog, Cricket Frog absent
BP-3 North Central Pit	+	Absent	+		NE		NE		2	Pickerel Frog absent
BP-3 South Central Pit	+	Absent	NE		+	+			2	Pickerel Frog absent
BP-3 South Pit	+	Absent	+	NE	+	+	NE		2	Pickerel Frog absent
BP-4	Absent	+	+		-	-			1	Spring Peeper absent; Bullfrog, Green Frog<background
BP-5	Absent		-		+	+			1	Spring Peeper absent; Fowlers Toad<background (present but not calling)
BP-5A	Absent	Absent	+	Absent	+	Absent	NE		1	Spring Peeper,Pickerel Frog, American Toad, Green Frog absent
BP-8A	-	Absent	+		+	+		Absent	1	Pickerel Frog, Cricket Frog absent; Spring Peeper<background
BP-8B	-	Absent	+		+	-	NE		1	Pickerel Frog absent; Spring Peeper, Green Frog<background
BP-9	+	+	+		+	-		Absent	1	Cricket Frog absent; Green Frog<background (present but not calling)
BP-10B			NE		+	-			2	Green Frog<background
BP-13A			+	NE	-	Absent			1	Green Frog absent; Bullfrog<background
BP-14 North	+	Absent	Absent		+	+			1	Pickerel Frog, Fowlers Toad absent
BP-14 South	Absent		+		+	-			1	Spring Peeper absent; Green Frog<background
BP-17	+	Absent	NE		+	+			2	Pickerel Frog absent
BP-21	-		Absent	Absent	+	+	Absent		1	Fowlers Toad, American Toad, Gray Treefrog absent; Spring Peeper<background
BP-27	NE	+	+	+	+	+	Absent		2	Gray Treefrog absent
BP-28A	NE			Absent	+	+	Absent		1	American Toad, Gray Treefrog absent
BP-28B	NE	NE			+	+	+		3	
BP-31	-	Absent		Absent	+	+			1	Pickerel Frog, American Toad absent; Spring Peeper<background
BP-31A USX	-		Absent	Absent	Absent	+			1	Fowlers Toad, American Toad, Bullfrog absent; Spring Peeper<background
BP-31A Wheelabrator			+		-	-			1	Bullfrog, Green Frog<background
BP-37 North	+		NE		+	+	+	+	3	
BP-37 Central	-				NE	NE			2	Spring Peeper<background
BP-37 South	+	+	+	Absent	NE	-	+	+	1	American Toad absent; Green Frog<background
BP-37 Isolated	NE		+	NE		NE			3	
BP-39	+	+	+	+	+	+	+	+	3	
BP-40	+	+	+	+	+	+		+	3	
BP-40 West	+	NE	+		+	+		NE	3	
NT-A Main	-	+	+	NE	+	Absent	Absent		1	Green Frog, Gray Treefrog absent; Spring Peeper<background
NT-A South	-		+				+		2	Spring Peeper<background
NT-B North	+		Absent		NE	+	NE	NE	2	Fowlers Toad absent
NT-B South	+		+		NE	+	NE		3	
NT-2	-	+	+	Absent	+	+			1	American Toad absent; Spring Peeper<background
NT-3 North		NE	+	Absent	+	-			1	American Toad absent; Green Frog<background
NT-3 South	NE	NE	+	+	+	-	Absent		1	Gray Treefrog absent; Green Frog<background
NT-4 East	-	NE	+	+			+		2	Spring Peeper<background

TABLE 6-32

SOLID WASTE UNITS AND AREAS OF CONCERN
SURFACE COVER

SWMU/AOC Identification	Cover Description	Slope	Vegetation	Erosion Evidence
BP-1	Grey colored slag	Northern end slopes upward; South end-flat	Heavy; flat area to south with phragmites and trees; north side heavily wooded	None
BP-2 North	Grey colored slag	Little slope	Sparse	None
BP-2 South	Grey colored slag	Flat drains to central canal	Sparse	Erosion rills through berms
BP-3	Slag and ponded water	Flat	Heavy	None
BP-4	Gray, dark colored slag	Berms around sides, slopes inward	Around lagoon area; phragmites and vines	None, some drainage cuts along laydown area into lagoon
BP-5A	Ponded water over majority of SWMU	Berms around ponded water	Heavily around edges where berm exists	No evidence
BP-8	Grey colored slag	Flat no outward gradient	Sparse	None
BP-8A	Slag and ponded water	Berms of slag around edge	Phragmites present around edge of SWMU	None
BP-8B	Large open area of very coarse slag south of ponded water	Slopes inward; berms around water filled areas	Heavy around edges of ponded water	Minor inward to SWMU
BP-9	Slag and ponded water	Slopes inward	Sparse, around ponded water	None

TABLE 6-32 (Continued)

SWMU/AOC Identification	Cover Description	Slope	Vegetation	Erosion Evidence
BP-10	Slag	Flat	Sparse	None
BP-10A	Parking area, paved	Flat	N/A	None
BP-10B	Slag and ponded water	Steep, into pond	Sparse	None
BP-13	Dark grey to black slag cover	Large level area with little grade; small areas of ponded rainfall	Minimal grass cover at edges; no vegetation throughout major portions	Minor surface erosion present towards interior of SWMU; no large gullies or swales present
BP-13A	Slag and ponded water	Slopes inward	Some around perimeter	None
BP-14	Slag and ponded water	Slopes inward	Phragmites along SW side; scattered clumps of 3- to 15-foot high trees; plants and reeds in center	Minor from railroad tracks into center of SWMU
BP-15	Slag	Slopes inward	Grass and low plants	None
BP-17	Ponded water and dark grey to white slag	Level with shallow depressions, slopes inward	scattered areas of short grasses; mainly vegetated	None
BP-19	Light, grey colored, gravel size slag fragments	No grade; flat	None	None
BP-23, 24, and 25	Dark grey colored slag	Flat, slopes inward	Sparse	None
BP-26	Light grey colored	Flat, slopes	None	None
BP-27	Grey slag	Flat, slopes inward	Grass and heavy growth around pond	None

TABLE 6-32 (Continued)

SWMU/AOC Identification	Cover Description	Slope	Vegetation	Erosion Evidence
BP-28A	Natural soils and slag	Steep into pond	Heavy around perimeter	None
BP-28B	Dark grey slag	Steep into pond	Heavy around perimeter	None
BP-29	Slag & pavement	Steep into Biles Creek	Heavy along creek	None
BP-30	Dark grey slag	Steep into Biles Creek	Heavy along creek	None
BP-31, 31A	Slag	Slopes inward	Heavy	None
BP-32	Grey color; half-inch in diameter	Northern side slopes inward; no slope to south	Sparse	None
BP-33	Natural soil, slag	Steep inward	Heavy	None
BP-35 A-C	N/A	Steep into pit	Sparse, some grass and bushes	None
BP-37	Natural soil, slag	Slopes inward	Heavy	None
BP-38	Natural soil, slag	Slopes inward	Heavy	None
BP-39	Natural soil, slag	Slopes inward, except Northeast corner towards River	Heavy	None
BP-40	Natural soil, slag	Slopes inward	Heavy	None
NT-1	Light to dark colored gravel size slag fragments	No slope; elevation lower than adjacent railroad tracks	Very little; grass; weeds	None

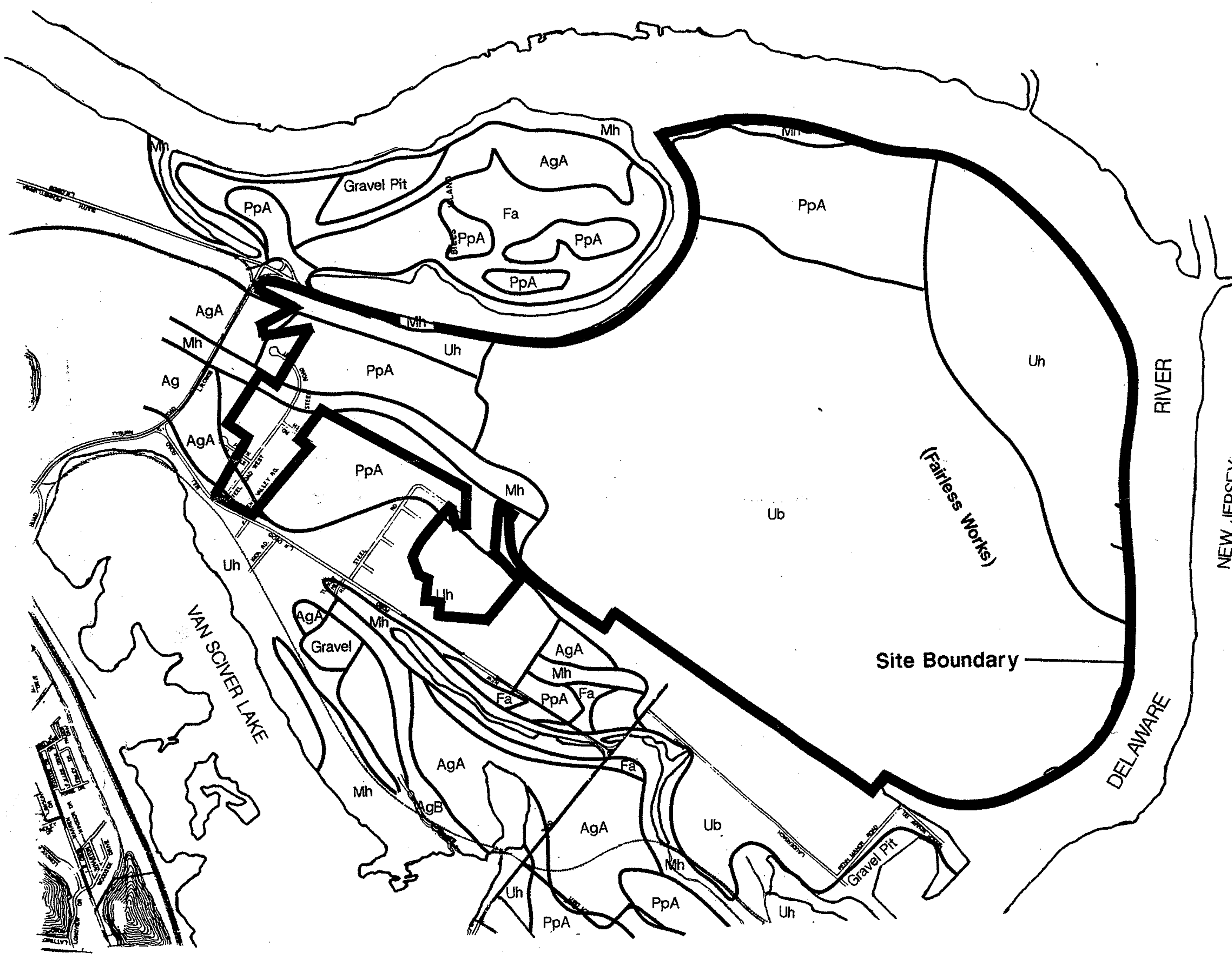
TABLE 6-32 (Continued)

SWMU/AOC Identification	Cover Description	Slope	Vegetation	Erosion Evidence
NT-2	Water at southern end; filled to grade and rest of SWMU vegetated	Flat; no slope except along western edge; on same elevation as railroad tracks	Good grass cover	None
NT-3	Open water areas at northern end; remaining SWMU heavily vegetated	Steep slopes into SWMU from road	Heavy; phragmites	None
NT-A	Open pit	Slopes into pit; approximately 15 feet below grade	Heavy around perimeter; phragmites; trees; bushes	None

Source: BCM Engineers Inc., Project No. 00-5039-7023

FIGURES

BCM



LEGEND

AgA	Alton Gravelly Loam (0-3% slopes)
AgB	Alton Gravelly Loam (3-8% slopes)
Fa	Fallsington Silt Loam
Mh	Marsh
PpA	Pope Loam
Uh	Urban Howell Complex
Ub	Urban Land

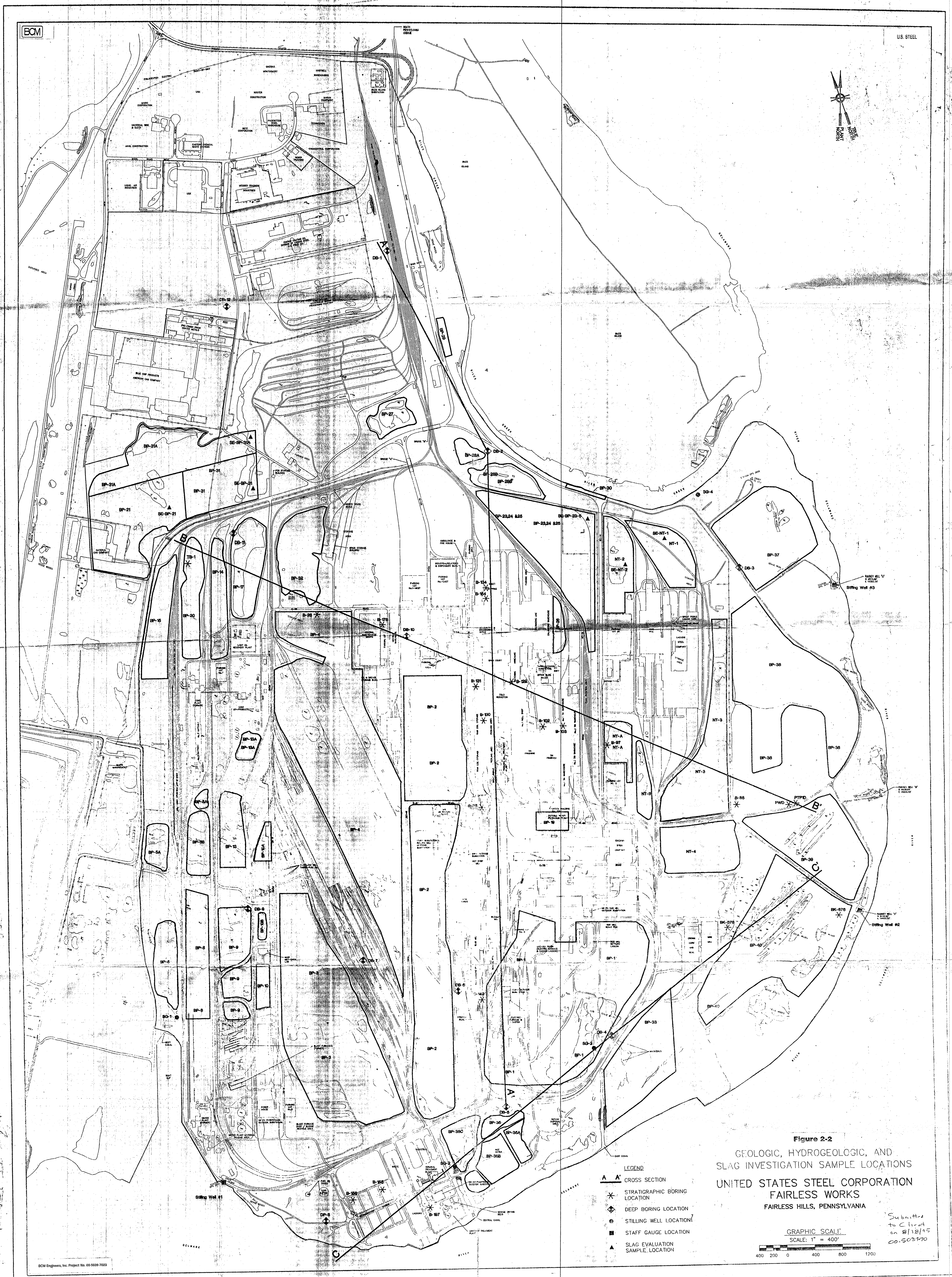
SOU : USDA Soil Survey of Bucks and Philadelphia Counties Pennsylvania, 1971; Zon ap of Falls Township, Bucks County, PA

BCM Engineers, Inc. Project No. 00-5039-7023

0 2400 FT

NORTH

Figure 2-1
Soil Map, Fairless Works



LEGEND

A A'	CROSS SECTION
✳	STRATIGRAPHIC BORING LOCATION
◈	DEEP BORING LOCATION
●	STILLING WELL LOCATION
■	STAFF GAUGE LOCATION
▲	SLAG EVALUATION SAMPLE LOCATION

Figure 2-2

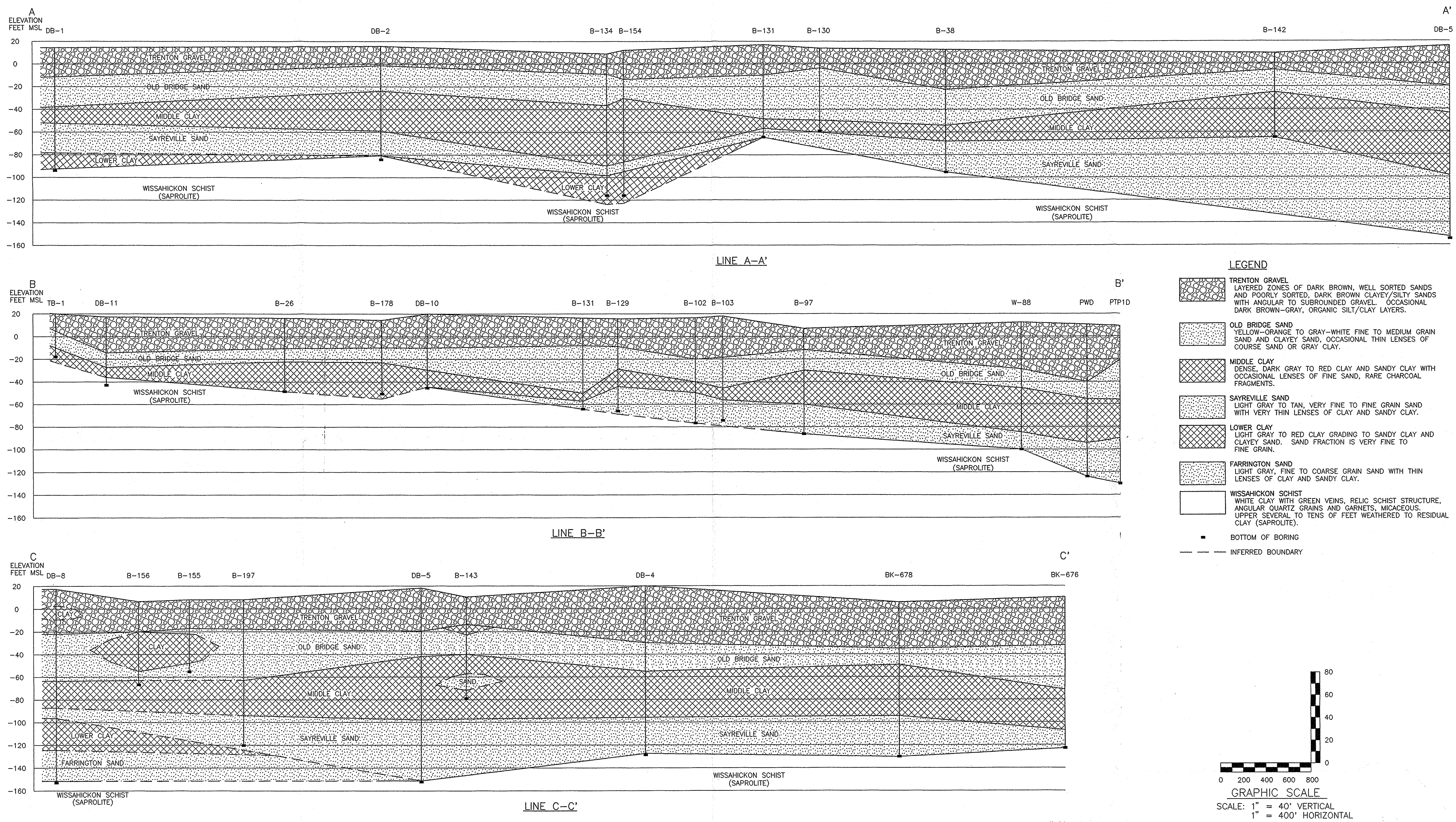
GEOLOGIC, HYDROGEOLOGIC, AND SLAG INVESTIGATION SAMPLE LOCATIONS

UNITED STATES STEEL CORPORATION
FAIRLESS WORKS

FAIRLESS HILLS, PENNSYLVANIA

GRAPHIC SCALE
SCALE: 1" = 400'
400 200 0 400 800 1200

Submitted to Client on 8/18/95
00-5037-70



NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR
1	REVISED IN RESPONSE TO EPA COMMENTS	6/11/96	SW		

BCM Engineers Inc.

One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST	AEP
DRAWN BY	RME
PROJECT GEOLOGIST	STW
PROJECT MGR.	BRC
CHECKED BY	BRC

APPROVED

APPROVED

DATE 9/19/97

SEAL: COMMONWEALTH OF PENNSYLVANIA, REGISTERED PROFESSIONAL, BRUCE R. CUSHING, GEOLOGIST 0032-G

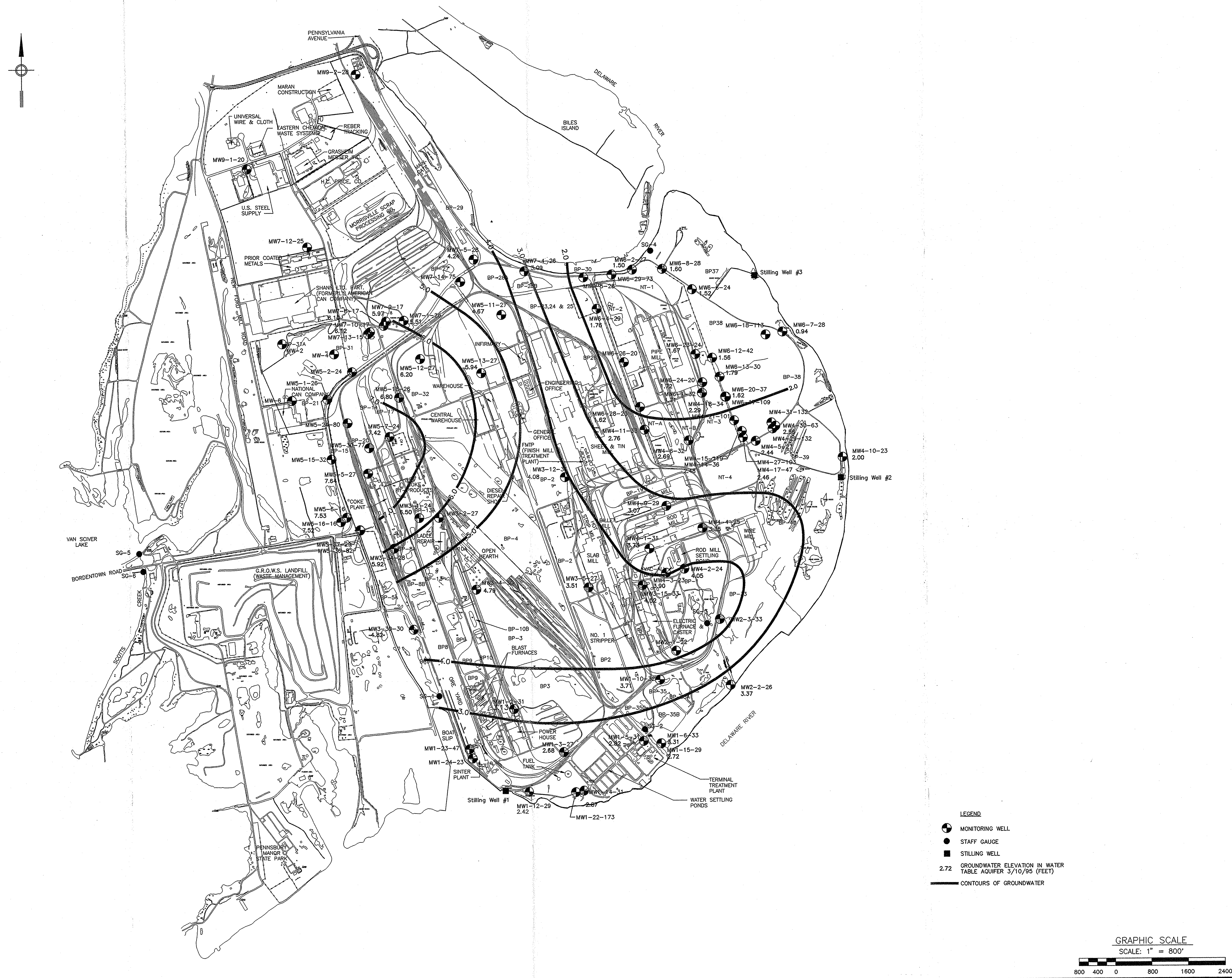
REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

STRATIGRAPGIC CROSS SECTION

SCALE	AS SHOWN
PROJECT NO.	00-5039-7023
DRAWING NO.	FIGURE 2-4
SHEET	OF

Drawing: USX-XSEC



NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM Engineers Inc.

One Plymouth Meeting
Plymouth Meeting, PA 19462

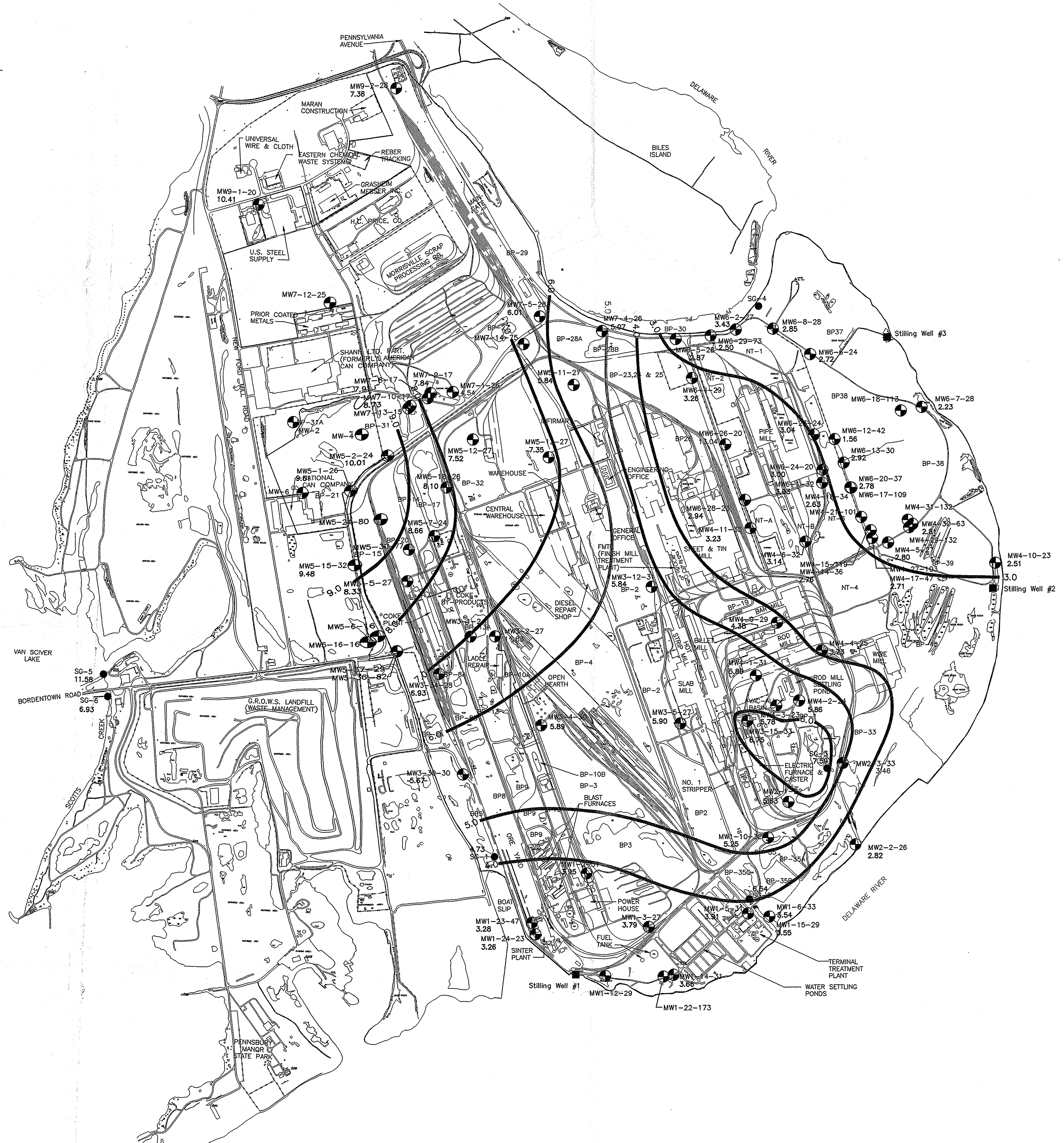
PROJECT HYDROGEOLOGIST AEP	APPROVED	SEAL
DRAWN BY RME		
PROJECT GEOLOGIST STW	APPROVED	
PROJECT MGR. BRC		
CHECKED BY BRC	DATE 9/19/97	

COMMONWEALTH OF PENNSYLVANIA — REGISTERED PROFESSIONAL — BRUCE R. CUSHING — GEOLOGIST 0022-G

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

GROUNDWATER CONTOUR MAP
WATER TABLE AQUIFER
MARCH 10, 1995

SCALE	AS NOTED
PROJECT NO.	00-5039-7023
FIGURE NO.	FIGURE 2-25
SHEET	OF



LEGEND

- MONITORING WELL
- STAFF GAUGE
- STILLING WELL
- 2.82 GROUNDWATER ELEVATION IN WATER TABLE AQUIFER 9/4/96 (FEET)
- CONTOURS OF GROUNDWATER
- 13.04 GROUNDWATER ELEVATION IN WATER TABLE AQUIFER (FEET) MEASURED 9/4/96 DROPPED FROM VERIFICATION DATA SET DUE TO INCONSISTENCIES WITH SURROUNDING DATA

GRAPHIC SCALE

SCALE: 1" = 800'

800 400 0 800 1600 2400

NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM BCM Engineers Inc.

One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST AEP	APPROVED	SEAL
DRAWN BY RME		
PROJECT GEOLOGIST STW	APPROVED	
PROJECT MGR. BRC		
CHECKED BY BRC	DATE 9/19/97	

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL
BRUCE R. CUSHING
GEOLOGIST 0032-G

REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

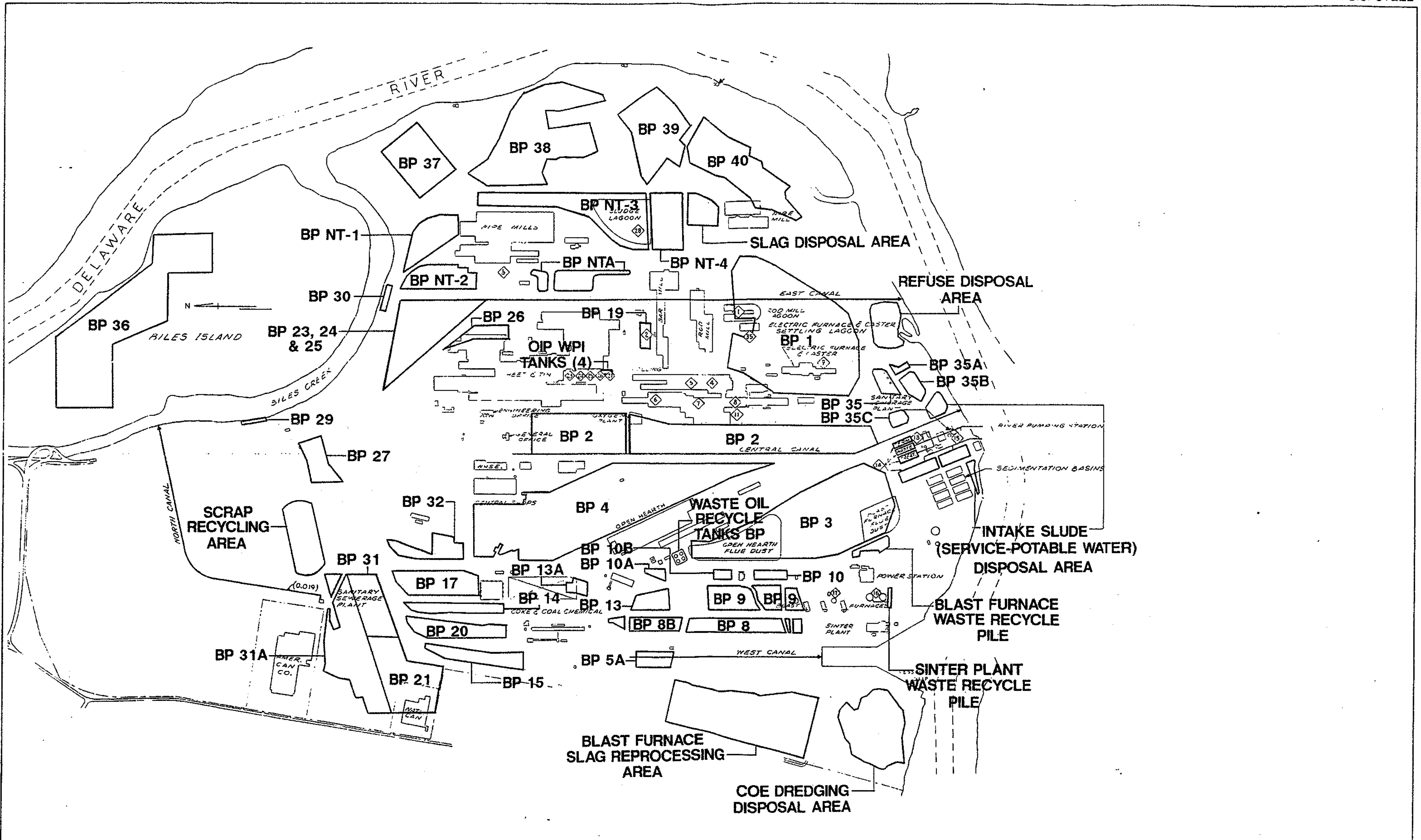
GROUNDWATER CONTOUR MAP
WATER TABLE AQUIFER
SEPTEMBER 4, 1996

SCALE	AS NOTED
PROJECT NO.	00-5039-7023
FIGURE NO.	FIGURE 2-27
SHEET	OF

Drawing: U-FIG-1
Xrefs: USX-1.DWG

BCM

U.S. STEEL



SOURCE: United States Steel Corporation 1972

BCM Engineers, Inc. Project No. 00-5039-7023

Figure 3-1
Solid Waste Management Units (SWMU)
USX Fairless Works

NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM Engineers Inc.
One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST AEP	APPROVED	SEAL
DRAWN BY RME		
PROJECT GEOLOGIST STW	APPROVED	
PROJECT MGR. BRC	DATE 9/19/97	
CHECKED BY BRC		

REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

GROUNDWATER FLOW MODEL VERIFICATION
PARTICLE PATHS FROM SELECTED AREAS
BP-3, BP-5A, BP-19, AND NT-2

SCALE	AS SHOWN
PROJECT NO.	00-5039-7023
FIGURE NO.	FIGURE 5-28
SHEET	OF

LEGEND

- PARTICLES STARTING AT BP-4
- PARTICLES STARTING AT BP-10A

SHALLOW WATER TABLE WELL
DEEP WATER TABLE WELL
CONFINED AQUIFER WELL
SHALLOW WATER TABLE WELL COMPLETED DECEMBER 1996
DEEP WATER TABLE WELL COMPLETED DECEMBER 1996
CONFINED AQUIFER WELL COMPLETED DECEMBER 1996
SHALLOW WATER TABLE WELL COMPLETED AUGUST 1996
DEEP WATER TABLE WELL COMPLETED AUGUST 1996
CONFINED AQUIFER WELL COMPLETED AUGUST 1996

GRAPHIC SCALE
SCALE: 1" = 800'
800 400 0 800 1600 2400

NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM Engineers Inc.
One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST AEP	APPROVED	SEAL
DRAWN BY RME		
PROJECT GEOLOGIST STW	APPROVED	
PROJECT MGR. BRC		
CHECKED BY BRC	DATE 9/19/97	

COMMONWEALTH OF PENNSYLVANIA REGISTERED PROFESSIONAL BRUCE R. CUSHING GEOLOGIST 0032-G

REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

GROUNDWATER FLOW MODEL VERIFICATION
PARTICLE PATHS FROM SELECTED AREAS
BP-4 AND BP-10A

SCALE	AS SHOWN
PROJECT NO.	00-5039-7023
FIGURE NO.	FIGURE FIG529
SHEET	OF

Drawing: U-FIG-2
Xrefs: PARTICLE.DWG USX-1.DWG

LEGEND

- PARTICLES STARTING AT BP-13
- PARTICLES STARTING AT BP-13A
- PARTICLES STARTING AT BP-27
- PARTICLES STARTING AT BP-35
- PARTICLES STARTING AT NT-1
- PARTICLES STARTING AT NT-4

SHALLOW WATER TABLE WELL
DEEP WATER TABLE WELL
CONFINED AQUIFER WELL
SHALLOW WATER TABLE WELL COMPLETED DECEMBER 1996
DEEP WATER TABLE WELL COMPLETED DECEMBER 1996
CONFINED AQUIFER WELL COMPLETED DECEMBER 1996
SHALLOW WATER TABLE WELL COMPLETED AUGUST 1996
DEEP WATER TABLE WELL COMPLETED AUGUST 1996
CONFINED AQUIFER WELL COMPLETED AUGUST 1996

NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM Engineers Inc.

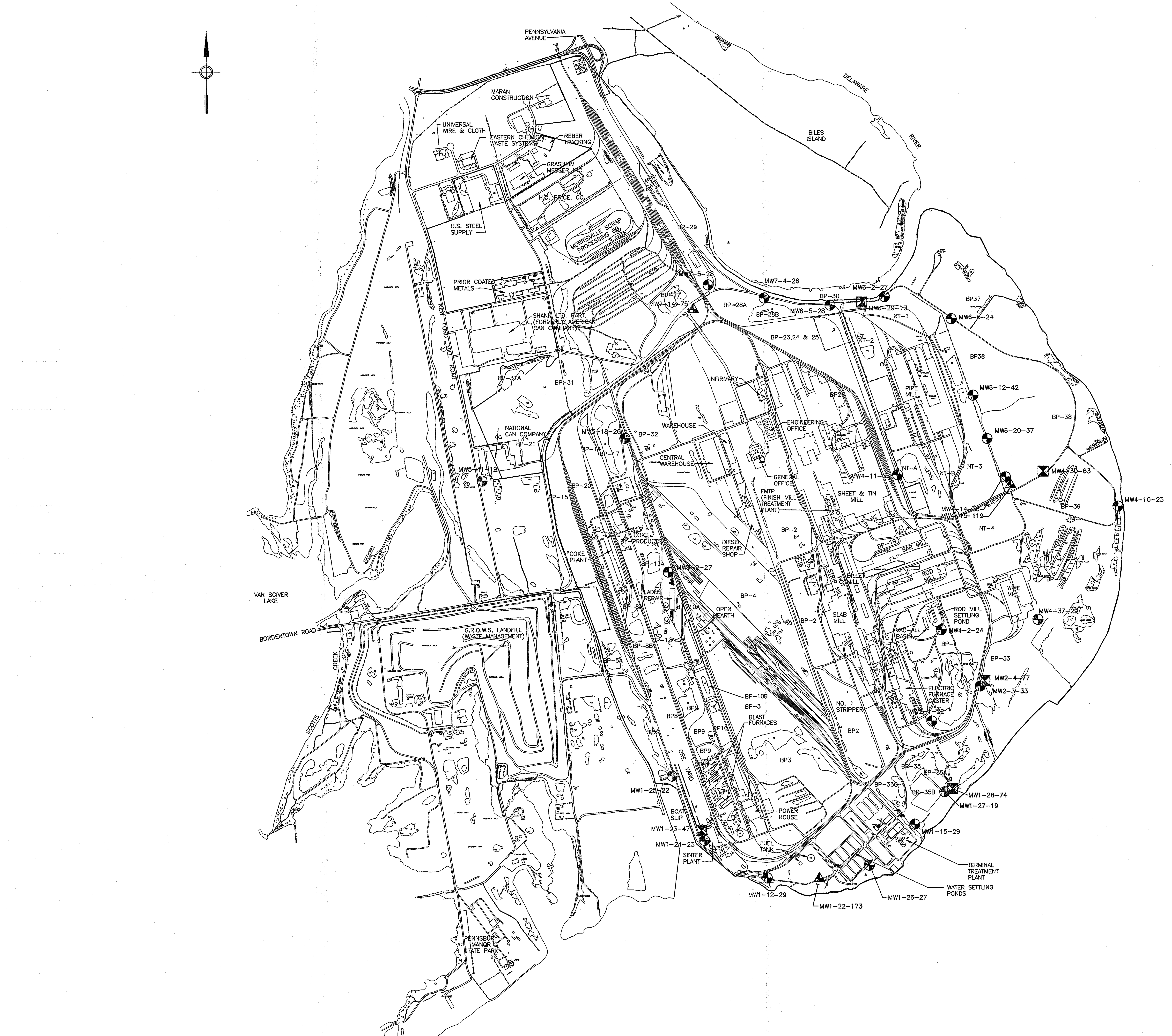
One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST AEP
DRAWN BY RME
PROJECT GEOLOGIST STW
PROJECT MGR. BRC
CHECKED BY BRC
APPROVED
APPROVED
DATE 9/19/97
SEAL
BRUCE R. CUSHING
REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

GROUNDWATER FLOW MODEL VERIFICATION
PARTICLE PATHS FROM SELECTED AREAS
BP-13, BP-13A, BP-27, BP-35, NT-1 AND NT-4

SCALE AS SHOWN
PROJECT NO. 00-5039-7023
FIGURE NO. FIGURE 5-33
SHEET of



LEGEND

- SHALLOW WATER TABLE WELL
- DEEP WATER TABLE WELL
- CONFINED AQUIFER WELL
- SHALLOW WATER TABLE WELL COMPLETED DECEMBER 1996
- DEEP WATER TABLE WELL COMPLETED DECEMBER 1996
- CONFINED AQUIFER WELL COMPLETED DECEMBER 1996
- SHALLOW WATER TABLE WELL COMPLETED AUGUST 1996
- DEEP WATER TABLE WELL COMPLETED AUGUST 1996
- CONFINED AQUIFER WELL COMPLETED AUGUST 1996

GRAPHIC SCALE

SCALE: 1" = 800'

800 400 0 800 1600 2400

NO.	REVISIONS	DATE	ENGR.	NO.	REVISIONS	DATE	ENGR.	DATE	ISSUED FOR

BCM Engineers Inc.

One Plymouth Meeting
Plymouth Meeting, PA 19462

PROJECT HYDROGEOLOGIST AEP	APPROVED	
DRAWN BY RME		
PROJECT GEOLOGIST STW	APPROVED	
PROJECT MGR. BRC		
CHECKED BY BRC	DATE 9/19/97	

SEAL: COMMONWEALTH OF PENNSYLVANIA, REGISTERED PROFESSIONAL GEOLOGIST, BRUCE R. CUSHING, GEOLOGIST 0032-G

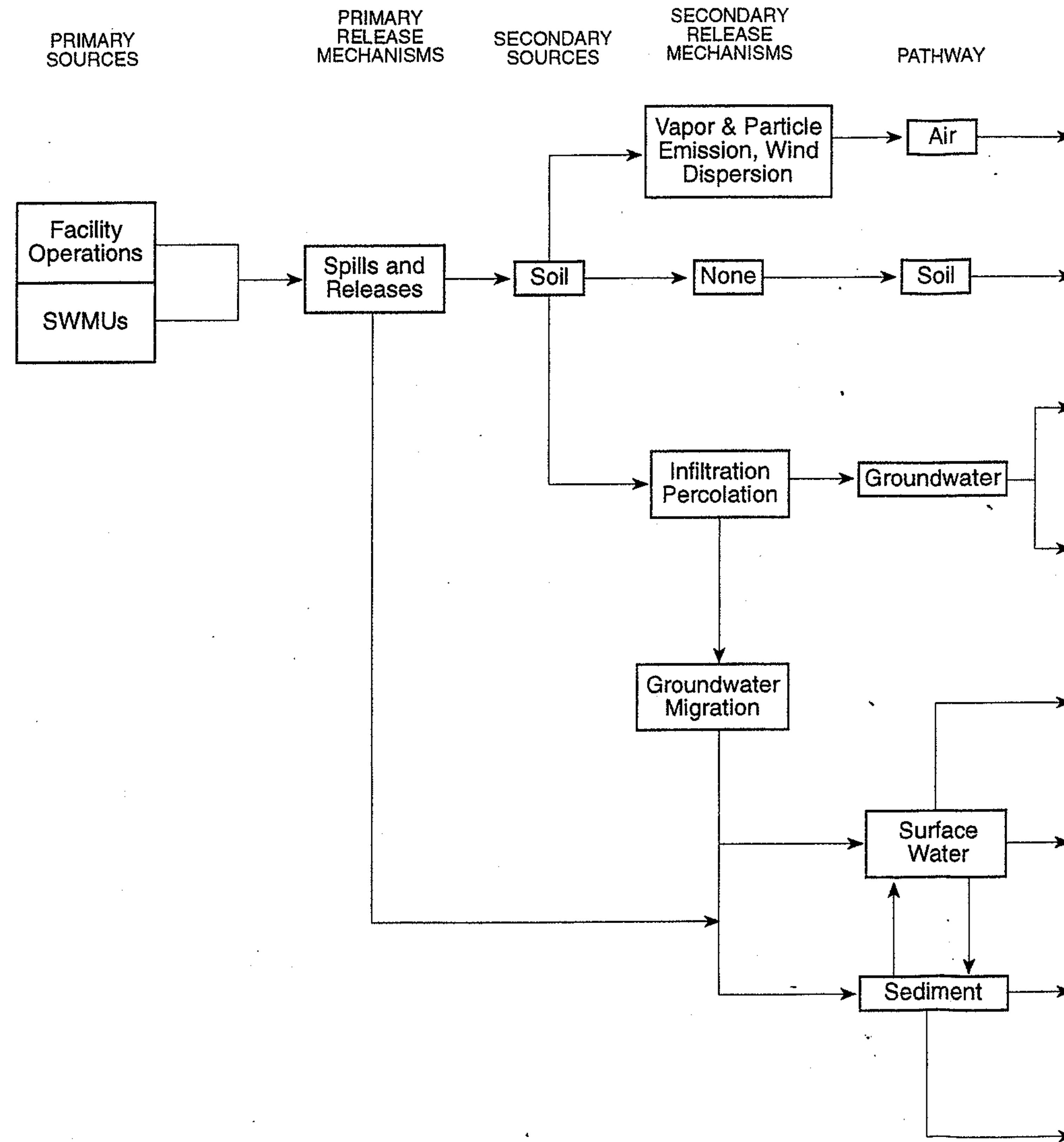
REGISTERED PROFESSIONAL GEOLOGIST

U.S. STEEL
FAIRLESS WORKS
FAIRLESS HILLS, PENNSYLVANIA

PROPOSED PHASE I RFI
GROUNDWATER MONITORING
WELL NETWORK

SCALE	AS NOTED
PROJECT NO.	00-5039-7023
FIGURE NO.	FIGURE 6-1
SHEET	OF

April 17, 1997 1:27:43 p.m. | Oper:rme
Drawing: U-FIG-1
Xrefs: FDU-1.DWG



POTENTIAL RECEPTORS

Pathway / Location / Route	Workers	Residents	Swimmers	Fishermen	Aquatic	Terrestrial
Air — Location: Onsite & Nearby Properties						
Inhalation						
Soil — Location: Onsite Exposed Wastes						
Dermal Contact	●					●
Ingestion	●					●
Groundwater — Location: Offsite						
Ingestion						
Dermal Contact						
Vapor Inhalation						
Groundwater — Location: Onsite						
Ingestion						
Dermal Contact						
Vapor Inhalation						
Surface Water — Location: Onsite Waters						
Ingestion					●	●
Dermal Contact					●	●
Vapor Inhalation						
Surface Water — Location: Delaware River						
Dermal Contact		●	●	●	●	●
Ingestion	●	●	●	●	●	●
Fish Ingestion		●		●	●	●
Sediment — Location: Onsite Waters						
Dermal Contact					●	●
Ingestion					●	●
Sediment — Location: Delaware River						
Dermal Contact				●	●	●
Ingestion					●	●

Figure 6-11
**Phase I RFI Conceptual Site Model
Fairless Works**

BCM

APPENDIX 2-2

STRATIGRAPHIC BORING LITHOLOGIC LOGS

BCM

COMPUTATION SHEET

Sheet Number 1 Of 3

Date 1/5/95

Job Number

Computed by ______ Checked by ______

Name of Client USX Fairless Works

Project Deep Boring #1 = CPT #1

Description CPT #1 =

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
4-6'	5, 4, 5, 5	Silty Sand	Very fine grain sand with little clay, light brown
10-12'	15, 14, 12, 26	Sand and Gravel	Silty sand, light brown with fine to medium grain gravel subrounded to rounded
14-16'	8, 7, 7, 6	no recovery	
19-21'	28, 50/5"	Sand	light brown, fine grain sand with little fine gravel.
24-26'	4, 5, 6, 7	Sand	same as above (19-21')
29'-31'	4, 2, 5, 5	Sand + Gravel	light brown, fine-coarse grained, well graded sand with rounded, fine-medium grained gravel
34-36'	6, 7, 14, 19	Sand & gravel	Same as above (29-31')
39-41'	27, 13, 14, 16	Sand-clayey sand	yellowish-white, fine grained, poorly graded sand with variable amounts of clay (0-40%)
44-46'	10, 26, 35, 45	Sand	yellowish-orange, fine grained poorly graded sand w/ little to no clay
49-51'	4, 15, 10, 14	Sand	same as above with a white, yellow clay plug @ the end of the spoon.
55-57'	7, 11, 11, 15	Sandy Clay	light gray, very fine grained sand w/ orange staining. Percentage of sand varies over interval (20-50%). Red clay zone as shown in cuttings (51-55')

Left margin: water 1.6; ?-18 ?/ele; OLD BRIDGE; ?-18

BCM

COMPUTATION SHEET

Sheet Number 3 Of 3
Date 1/5/95
Job Number
Computed by Checked by

Name of Client
Project
Description

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
95-97'			9½ - red/brown sand (stain) fragments w/ increasing depth clay becomes red and these red sand fragments acquire deep red color, possibly iron staining preferential to pockets of higher permeability clay is deep red at top of spoon)
100-102	7, 8, 12, 17	clay	Orange to red. Last 0.5' has gray/green "veins" of discoloration
105-107	9, 15, 19, 23	Saprolite	white clay w/ light green veins, relic fabric, siltstone appearance some fine sand

LB

CM COMPUTATION SHEET

Sheet Number 2 of 2
Date 11/2/94
Job Number
Computed by Checked by

Client USX Fairless Works
ct Deep Boring Location No. 2
iption
oon

-61' Sand: medium grain, occasional clay and fine sand lenses, gray (SP)

-66' (64-64.5') Sandy Clay: (SC) medium grain, light gray

(64.5'- Clay: (CH) w/ very fine to fine grain sand, light gray w/ orange laminae, dense

-71' Clay: (CH) w/ fine sand, occasional lenses of fine sand, light gray to tan

-73' Clay - as above, Shelby Tube Collected

-76' Clay: (CH) trace very fine sand, occasional fine grain sand lenses, medium gray color, dense
OC, Cation

81' (79-79.5') Sandy Clay: 40% fine grain sand, medium gray

(79.5'-80.9') Sand: poorly graded, fine grain, light gray with black + orange staining (SP)

(80.9'- Sandy Clay: medium gray

-86' Sand: clayey fine grain, poorly graded, light tan to orange (SP)
OC, Cation

-91' Sand: poorly graded, fine grain with little medium to coarse grain, orange with black fine grain sand. (SP)

-96' Sandy Clay: (CL) 30-40% fine grain sand, relic fabric, sands are black, red, micaceous, quartz, garnet? (Saprolite)
OC, Cation

9- Saprolite as above - refusal

End of Boring

DB#3

BCM

COMPUTATION SHEET

Sheet Number 1 of ____
Date 12/12/94
Job Number 00 5039 7012
Computed by RCN Checked by ____

of Client USX FAIRLESS WORKS
Project CPT (SPLIT SPOON)
Description CPT #3

CPT TESTING ~ 0-56'

SPLIT SPOON SAMPLING 60' - BEDROCK (@ EVERY 5 FEET)

DEPTH	SOIL CLASSIFICA.	MATERIAL	DESCRIPTION
60 - 62'	SW	SAND	Yellow - lgt brown, well sorted, well rounded grains of sand, with lenses of black, v. fine grained sand. The top 2" included some multi-colored, fine, subrounded gravel.
65 - 67'	SW	SAND	yellowish - orange, fine grained, well sorted, round sand.
~~6~~70 - 72'		SAND	Same as above w/ little clay.
75 - 77'		SAND	Same as above.
80 - 82'	SW	SAND	Sand - same as above w/ out trace clay or fines.
85' - 87'	SW	SAND	Yellow - lgt grey w/ orange staining, v. fine grained, poorey graded sand with v. fine black sand grains
90' - 92'	SW	SAND	Same as above.
95 - 97	SP	SAND (95.0 - 95.5)	yellow orange, poorly sorted, coarse to medium grained, subangular sand w/ occassional fine gravel.
	ML	SANDY CLAY	Light grey, medium stiff, sandy clay. Contains 30 - 40% fine grained sand.
98 - 100'		Sandy clay	lgt grey w/ orange + blk staining sandy clay. Contains ~40 - 50% v. fine grained sand.
105 - 107'		SAND (105 - 106' 6")	yellow - lgt grey w/ orange staining, fine grained sand with lenses of v. fine grained, black sand. W/ a 2" lense of clayey sand @ 105' 2"
		SANDY CLAY	light grey w/ 40 - 50% fine grained sand.

UO' T

BCM

COMPUTATION SHEET

Sheet Number 1 of 3
Date 12/14/94
Job Number 0050397012
Computed by PCN Checked by

Name of Client USX – Fairless Works
Project SPLIT SPOON BORINGS
Description ~~CPT #4~~ DB#4

TO CORRECT DEPTHS TO ELEVATION (SUBTRACT 8 FT)

DEPTH	SOIL	DESCRIPTION
4-6' (+4 - +6)	FILL	SLAG – W/ LITTLE BITS OF YELLOW ORANGE SAND.
9-11' 3GL (-1 to -3)	FILL	SLAG – SAME AS ABOVE
14-16' (- 6 - 8)	FILL	SLAG – DK. BROWN W/ FINES + ORGANIC MATTER
19-21' (-11 - -13)	CLAY	DK. BROWN, RED W/ 20% FINE GRAINED SAND.
*		→ RICK EMPSON MOVES HOLE ~ 6 FT EAST AND BEGINS DRILLING AGAIN (HE HIT AN OBJECT ~ 13' AND THE HOLE IS DRILLING CROOKED.
24-26' (-16 - -18)		0" RECOVERY
29-31' (-21 -23)	CLAYEY SAND	FINE GRAINED, WELL GRADED SAND W/ ~30% CLAY, COLOR VARIABLE. TOP 2" GREY BROWN 3-6" BLACK 6-18" RED. CLAYEY SAND ALSO CONTAINS SUBANGULAR – SUBROUNDED GRAVEL.
34-36' (-26 - -28)	SAND + GRAVEL	– LGT. BROWN, FINE GRAINED, WELL GRADED SAND W/ ~30% FINE SUBANGULAR GRAVEL
39-41' (-31 - -33)	SAND + GRAVEL	SAME AS ABOVE
44-46' (-36 - -38)	SAND	LGT. GREY, FINE GRAINED, POORLY GRADED W/ NO FINES
49-51' --41 -43	SAND	49-49.5" – LGT. BROWN, WELL GRADED W/ MULTICOLORED (RED, BLACK, YELLOW) COARSER GRAINS. (MEDIUM – FINE GRAIN SIZE RANGE) 49.5 – WHITE – LGT. YELLOW POORLY GRADED FINE GRAIN SAND.

PENTON GRAVEL

OLD BRIDGE

DB #4

COMPUTATION SHEET

BCM

Name of Client: USX FAIRLESS WORKS

Project: CPT (SPLIT SPOON)

Description: CPT #4

Sheet Number: 3 of 3

Date: 12/14/94

Job Number: 005039-7012

Computed by: PCN Checked by:

DEPTH	SOIL TYPE	DESCRIPTION
105-107 97-99	CLAY	RED + LGT GREY MOTTLED CLAY w/ LITTLE SAND (STIFF).
PDLE CLAY		→ RICK EMPSON STATES HE IS DRILLING THROUGH LENSES OF SAND + CLAY
110-112 102 104	CLAY	110'-111'2" - CLAY - LGT GREY w/ 30% FINE GRAINED SAND. 111'2" - CLAYEY SAND LGT GREY SAND w/ 40-50% LGT GREY CLAY.
115-117 107 109	CLAYEY SAND	115'-115'7" CLAYEY SAND - YELLOWISH ORANGE FINE GRAINED w/ ~30-40% CLAY
	SANDY CLAY	115'7" - SANDY CLAY LGT GREY w/ ~40% FINE GRAINED SAND.
120-122 112 114	CLAYEY SAND	CLAYEY SAND w/ LENSES OF HIGHER CLAY CONTENT. LGT GREY, FINE GRAINED SAND w/ A CLAY CONTENT WHICH RANGES FROM 40 TO 90% (IN LENSES).
4YRB ILLB 125-127 117-119	SAND	LGT GREY, FINE GRAINED, POORLY GRADED SAND w/ BLACK STREAKS OF SAND.
130-132 122-124	SAND	SAME AS ABOVE
135-137 127-129	SAND	SAME AS ABOVE w/ V. FINE GRAINED BLACK THROUGHOUT.
140-142 132-134	SAND	SAME AS ABOVE w/ LENSES OF SOFT ORGANIC BLACK MATTER (WOOD?) AND LENSES OF SOFT WHITE CLAY.
145-147 137-139	—	SAPPROLITE WHITE CLAY w/ ~~GNEISS~~ MICA, PIECES OF QUARTZ + RELIC STRUCTURE

DB #5

BCM

COMPUTATION SHEET

Name of Client: USX - FAIRLESS WORKS

Project: CPT (SPLIT SPOON)

Description: CPT #5

Sheet Number 2 of 4

Date 12/20/94

Job Number

Computed by ______ Checked by ______

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
60-62'	9, 19, 26, 36	SANDY CLAY	LGT GREY - DK GREY CLAY W/ V. FINE GRAINED SAND (~40%) AND LENSES OF SAND (AS DESCRIBED IN 55-57')
65-67'	**, 33, 45	CLAY GRADING INTO A SAND.	BLK CLAY (TOP 2") W/ LITTLE SAND MAKES SHARP CONTACT W/ LGT GREY SANDY CLAY WHICH GRADES INTO A SAND W/ LITTE CLAY.
			** ROD FELL INTO HOLE AND SPOON ADVANCED 1'. BLOW COUNTS REPRESENT ADVANCEMENT OF LAST FOOT.
70-72	7, 12, 18, 27	SANDY CLAY	LGT GREY CLAY W/ V. FINE GRAINED SAND (~20-30%)
			→ DRILLER STATES WE HIT CLAY @ ~68'
75-77	13, 21, 25, 31	CLAY	CLAY - LGT GREY, MEDIUM STIFF, LITTLE TO NO SAND.
80-82	9, 25, 30, 44	CLAY	MEDIUM GREY CLAY W/ DECOMPOSED WOOD.
85-87	25, 38, 50/5"	CLAY	LGT GREY W/ SOME FINE GRAINED SAND. 86'6" - CLAYEY SAND LGT GREY, FINE GRAINED SAND W/ SOME CLAY (~40%).
90-92	27, 50/5"	SANDY CLAY	LGT GREY - LGT BROWN SAND W/ VARIABLE AMOUNT OF V. FINE GRAINED SAND + SILT (10% to 40%)

ORIENGE (?)

CLAY

DB #5

BCM

COMPUTATION SHEET

Sheet Number CONTINUED FROM PREVIOUS SETS of 4/4

Date 12/20/94

Job Number

Computed by RLN Checked by

Name of Client USX FAIRLESS WORKS

Project CPT (SPLIT SPOON)

Description CPT #5

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
115-117	12, 40, 50/5"	CLAY	115-115'8" - LGT GREY CLAY W/ VARIABLE AMOUNTS OF SAND (~20% - 40%)
		SAND	115'8" - LGT GREY, POORLY GRADED, FINE GRAINED SAND.
120-122'	37, 43, 50/5"	SAND	LGT GREY, POORLY GRADED, FINE GRAINED SAND
125-127	27, 50/5"	SAND	SAME AS ABOVE
~~135-1?~~ 130-132	37, 50/5"	SAND	SAME AS ABOVE
135-137	20, 25, 34, 42	SAND + CLAY	LGT GREY, GRADED (MED-FINE GRAINED) SAND W/ LENSES OF LGT GREY CLAY W/ V. FINE GRAINED SAND.
140-142	23, 26, 39, 47	SAND	LGT. GREY, POORLY GRADED, FINE GRAINED SAND
145-147	27, 44, 50/~~5~~4"	SAND	LGT GREY, FINE GRAINED, POORLY GRADED) WITH LENSES OF OF MEDIUM GREY CLAY
150-152	29, 50/5"	—	NO RECOVERY
155-157	32, 35, 40, 42	SAND	SAME AS ABOVE (145-147')
160-162	20, 27, 30, 50/5'	SAND	SAME AS ABOVE (145-147) WITH FINE, SUBROUNDED GRAVEL + PIECES OF QUARTZ
165-167	20, 37, 34, 35	SAND + CLAY	LGT GREY SAND (GRADED MED - FINE) WITH LENSES (1"SCALE) OF CLAY. CLAY CONTAINS SOME DECOMPOSED WOOD
167-169	19, 22, 31, 47	SAPPROLITE	

DB #6

BCM

COMPUTATION SHEET

Sheet Number 2 of 3
Date 12/20/94
Job Number 0050397012
Computed by PCW Checked by

Name of Client USX FAIRLESS WORKS
Project CPT / (SPLIT SPOON).
Description CPT#6

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
60-62	4, 5, 6, 8	SAND + GRAVEL	SAME AS ABOVE (55-57).
65-67	8, 9, 8, 6	SAND + GRAVEL	SAND (MED-FINE) GRAINED, GRADED W/ FINE GRAINED GRAVEL YELLOWISH ORANGE W/ SOME ORANGE STAINING.
70-72'	7, 9, 8, 14	CLAY	LGT GREY + RED MOTTLED W/ OUT SAND.
75-77	8, 12, 14, 21	CLAY	SAME AS ABOVE.
80-82'	~~CLAY~~ 10, 16, 23, 31	CLAY	Same as above.
85-87'	10, 10 14, 22	clay	same as above BUT with less red clay.
90-92'	14, 29, 24, 40	clay	same as above - w/ little fine grained sand.
95-97'	11, 20, 26, 39	clay	lgt grey w/ out sand or silt.
100-102'	14, 24, 28, 35	clay	lgt grey, red + olive green mottled clay w/ out sands.
105-107'	17, 24, 36, 40	sandy clay	med grey clay w/ variable amounts of sand (0-40%) and lenses of lgt grey, fine grained sand.
110-112	14, 37, 50/4"	sandy clay	med grey clay w/ 30-40% fine grained sand. (110-111'7") 111'7" - Lgt grey sand, fine grained + poorly graded.

BB #7

DB #7

BCM

COMPUTATION SHEET

Sheet Number 1 of 3

Date 12/27/94

Job Number 0050397012

Computed by BCN Checked by

Name of Client USX Fairless Works

Project CPT / SPLIT SPOON

Description CPT #7

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
4-6	9,7, 10,10	Clay + gravel	DK. Brown clay w/ little finegrained sand + some medium-coarse gravel
9-11'	7,9, 9,10	sand + gravel	DK. Brown sand (fine-medium grained) w/ some gravel (subangular-subrounded, med-finegrained, gravel)
14-16'	18,18, 10,12	sand	Lgt. Brown, fine grained, poorly graded sand w/ little fine grained, subrounded gravel
19-21'	2,3, 4,5	clayey sand	Lgt. Brown sand w/ variable clay content (20-40%). Sand is finegrained and poorly sorted.
24-26'	10,11, 6,10	Sand + gravel	Lgt. Brown, well graded (fine-coarse grained) sand with fine-medium grained gravel.
29-31	2,2, 3,5	Sand + gravel	Same as above (24-26)
34-36	5,6, 7,6	no recovery	
39-41	6,10, 15,24	Sand	Lgt. brown, well graded (medium-fine) sand grading into a white-yellow fine grained, poorly graded sand ~40'
44-46	13,31, 35,27	Sand	Yellow, fine grained poorly graded sand.
49-51	4,19, 32,40	Sand	49-49'6" - lgt brown, fine grained sand. 49'6"-50 yellow, medium grained poorly graded, clean sand.

DDF 1

COMPUTATION SHEET

BCM

Sheet Number 3 of 3
Date 12/27/94
Job Number 0050397012
Computed by RN Checked by

Name of Client USX Fairless works
Project CPT / SPLIT SPOON
Description CPT#7

Sayreville

Depth of Split Spoon	# of Blow counts	Soil Type	Description
105-107	39, 43, 50/5"	Sand	yellowish orange, fine grained poorly graded sand w/ little clay
110-112	20, 30, 35, 45	Sand	yellowish orange, fine-medium grained, graded sand.
115-117	29, 31, 34, 34	Sand	Same as above (110-112).
120-122	19, 31, 50/5"	Sand	same as above w/ lenses of white clay (1/4" scale).
125-127	40, 50/5"	Sand	Lgt. grey, fine grained, graded sand
130-132	26, 37, 46, 50/4"	clay	lgt grey, red + olive green mottled, medium stiff clay w/ little fine grained sand.
135-137	18, 20 25, 38	clay	Same as above
140-142	20, 20 27, 36	clay + sapprolite	140-140'6" Same as above 140'6" - relic structure and fractured quartz. Sapprolite

END OF BORING

DB #8

BCM **COMPUTATION SHEET**

Sheet Number 2 of 4
Date 11/3/94
Job Number
Computed by SJW Checked by

Name of Client USX Fairless Works
Project Deep Boring 8
Description

Spoon DESCRIPTION

49-51'
N=50/3" Sand: very fine grain, poorly graded, trace silt, light gray to white (SP)

*54-56' Sand: same as above (SP)

59-61' (59'-60.1') Clay: (CH) trace very fine sand, light gray
N=87
(60.1'- Sand: fine grain, poorly graded, trace silt or clay, light gray (SP)

64-66' Sand: as above, clean (SP)

*69-71' (69-70.9') Sand: as above (SP)
N=65
(70.9- Sandy Clay: (CH) medium gray, fine sand

74-76' (74-74.2') Clayey Sand (SC): fine grain, light gray
N=60
(74.2'- Sand: (SP) fine grain, poorly graded, clean, light gray

79-81' (79-80.5') Sand: as above, turning tan/yellow
N=32
(80.5'- Clay: silty, gray (CL)

84-86' (84-84.5') Clay: (CH), red with gray, dense, minor very fine sand
N=30
(84.5' Clay: as above, gray (CH)

86-88' Shelby TUBE COLLECTED - 14" RECOVERY RED CLAY

89-91'* Clay: (CH) Red with gray + brown mottles, Very Dense
N=39

94-96' (94-95.1) Clayey Sand (SC): poorly graded, fine grain sand, cohesive, light gray
N=61
(95.1- Sand: (SP) very fine to fine grain, trace clay or silt, gray

"D BRIDGE

MILL E CLAY

DB # 8

BCM

COMPUTATION SHEET

Sheet Number 4 of 4

Date 11/3/94

Job Number

Computed by ______ Checked by ______

Name of Client USX Fairless Works

Project Deep Boring 8

Description

SPOON	DESCRIPTION
149-151' N=64	Sand: fine grain, little medium grain, poorly graded, occasional black laminae of very fine sand, gray brown to light gray
154-156' N=65	Sand: fine to coarse, occasional clay lenses, well graded, trace gravel, light gray (SW)
* 159-161' N=50/4"	Sand: (SP) medium to coarse grain, light gray,
164-166' N=51	Clayey Sand: (SC) fine to coarse, light gray
	(165'-) Sandy Clay - (CL) fine to coarse grain (40%) light gray
* 169-171' N=48	SAPROLITE: Biotite, quartz, white clay, foliated relic structure.

SAYREVILLE

END OF BORING

BCM

COMPUTATION SHEET

Sheet Number 2 Of 3
Date 1/4/95
Job Number
Computed by ________ Checked by ________

Name of Client
Project
Description CPT #9

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
60-62	8, 13, 22, 31	CLAY	LGT GRAY AND RED MOTTLED CLAY - MEDIUM STIFF
65-67	7, 13, 18, 22	CLAY	RED, LGT GRAY & WHITE MOTTLED CLAY W/ OUT FINES OR SAND MEDIUM STIFF.
70-72	15, 32, 50/5"	SAND	LGT GRAY, FINE GRAINED SAND W/ VARIABLE CLAY CONTENT (0-30%) IN LENSES (1-2" SCALE)
75-77	28, 40, 50/5"	SAND	LGT GRAY, FINE GRAINED SAND, POORLY GRADED W/ SOME CLAY (~20%)
80-82'	12, 12, 28, 37	SAND & CLAY	LGT-MEDIUM GRAY SAND GRADING INTO CLAY IN LENSES (3-4"). CLAY CONTENT VARIES FROM (0-70%) CLAY AND SAND BOTH CONTAIN LARGE (1/2") PIECES OF DECOMPOSED WOOD
85-87'	10, 17, 50/5"	CLAYEY SAND	LGT GRAY, CLAYEY, FINE GRAIN SAND W/ LARGE PIECES (1/2"-4") PIECES OF DECOMPOSED WOOD
90-92'	26, 26, 50/5"	SAND	LGT GRAY, FINE GRAIN SAND W/ LITTLE CLAY (~20%) AND LENSES OF CLAY (1" SCALE)
95-97'	8, 20, 21, 29	SANDY CLAY	MEDIUM GRAY CLAY W/ SOME FINE GRAINED SAND AND A LENSE (2") OF CLEAN, LGT GRAY FINE GRAIN SAND
100-102'	17, 14, 15, 24	SAND / SANDY CLAY	100-100.5 - SAND - LGT GRAY, YELLOWISH-ORANGE, MED-FINE GR. SAND. 100.5'- MEDIUM GRAY SANDY CLAY (V. FINE GRAIN), STIFF

DB#10 **BCM** COMPUTATION SHEET

Sheet Number 1 Of 1

Date

Job Number

Computed by Checked by

Name of Client USX FAIRLESS WORKS

Project DEEP BORING #10

Description

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
4-6'	24, 26, 50/2"	SILTY SAND & GRAVEL	FINE GRAIN SAND W/ SILT AND SOME SUBANGULAR TO ANGULAR GRAVEL, DARK BROWN.
9-11'	11, 21, 20, 16	SILTY SAND & GRAVEL	WELL GRADED SILT TO COARSE SAND W/ SUBANGULAR TO ROUNDED PEBBLES. DARK BROWN, MOIST
14-16'	1, 1, 1, 1	CLAYEY SILT	DARK BROWN, PLASTIC, TIP OF SPOON WET, LOOSE/SOFT.
19-21'	7, 7, 5, 5	SILTY SAND & GRAVEL	FINE TO COARSE GRAIN, ANGULAR TO ROUNDED GRAVEL, BROWN, WET, LOOSE
24-26	4, 5, 3, 2	GRAVEL & SAND (GW)	WELL GRADED, FINE TO COARSE SAND AND ANGULAR TO ROUNDED GRAVEL, LOOSE, BROWN, WET
9 29-31	1, 1, 1, 4	SAND (SW)	WELL GRADED, WELL WASHED FINE TO VERY COARSE SAND W/ ≈20% ROUNDED GRAVEL, WET, LOOSE
34-36	3, 10, 14, 21	SAND (SW)	WELL GRADED, FINE GRAIN, TAN W/ BROWN & ORANGE LAMINATIONS, MED DENSE, WET.
39-41	10, 14, 20, 18	SAND (SP) to CLAYEY SAND (SC)	FINE TO MEDIUM GRAIN FINING UP TO A CLAYEY SAND AND CLAY LAYERS, DENSE, LIGHT GRAY, TO TAN, WET.
44-46	3, 10, 22, 24	SAND (SP)	POORLY GRADED, FINE GRAIN, DENSE, ORANGE W/ BLACK LAMINAE
49-51	5, 10, 11, 19	CLAY (CL)	TRACE FINE SAND, VERY STIFF, TAN TURNING GRAY W/ RED
55-57	4, 6, 10, 11		NO RECOVERY

D10

COMPUTATION SHEET

BCM

Sheet Number 2 Of 2

Date

Job Number

Computed by ____ Checked by ____

Name of Client USX FAIRLESS WORKS.

Project DEEP BORING #11

Description

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
*			DRILLER SAYS - SAND + GRAVEL AT ~33' BG THEN SAND.
34-36'	6, 7, 1, 2	SAND	34-35.2 SAND (SP) FINE TO MEDIUM GRAIN, OCCASIONAL CLAY LENSES, OCCASIONAL COARSE GRA ZONES. TAN TO LIGHT GRAY, SUBANGULAR COARSE GRAINS, BLACK VERY FINE GRAIN SAND PRESENT THROUGHOUT.
39-41	16, 17, 18, 27	SAND	39 - SAND (SP) POORLY GRADED, FINE TO MEDIUM GRAIN, OCCASIONAL LENSES OF COARSE SAND, TRACE CLAY, LIGHT GRAY W/ TAN.
44-46'	6, 9, 10, 12	SANDY CLAY	FINE GRAIN SAND, LAMINATED ORANGE AND LIGHT GRAY. DENSE. 44.5' - AS ABOVE, LIGHT GRAY OCCASIONAL THIN FINE SAND LAMINAE GRAY STUFF HAS HIGHER SAND CONTENT CLAYEY.
49-51'	8, 10, 12, 18	CLAY	DARK GRAY, OCCASIONAL ZONES OF FINE GRAIN SANDY CLAY AND FINE SAND LAMINAE. TOUGH, DENSE, DARK GRAY CONCOIDAL PARTING.
55-57	10, 12, 18, 25	SAPROLITE	RELIC FABRIC - CHLORITE SCHIST W/ MED GRAIN QUARTZ GRANULES. CHLORITE, FELDSPAR ALTERED TO CLAY.
60-62'	11, 14, 22, 26	SAPROLITE	AS ABOVE - GARNETS & RED STAINING

OLD BRIDGE

COMPUTATION SHEET

BCM

Name of Client

Project

Description

Date

Job Number

Computed by Checked by

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
49-51	6, 10, 13, 16	CLAY	LIGHT GRAY, VERY STIFF, RED DENDRITIC COLORATION. AS ABOVE BUT MORE GRAY COLOR
55-57	8, 13, 18, 27	CLAY (CH)	GRAY & RED TRACE, VERY FINE SAND, VERY STIFF TO HARD
58-60'	10, 18, 21, 33	SILTY CLAY (CL)	TRACE, VERY FINE SAND, GRAY W/ RED, VERY STIFF TO HARD, DIFFICULT DRILLING
65-67	12, 16, 25, 32	CLAY & SILTY SAND	INTERMIXED, LAYERED, DARK GRAY VERY STIFF CLAY AND SILTY CLAY LAYERED W/ SILTY SAND (SM). FINE GRAIN, POORLY SORTED, MEDIUM DENSE, GRAY, CLAY HAS SOME SILTY CLAY ZONES, 10-15% ORGANIC FRAGMENTS (BLACK).
70-72	17, 21, 32, 34	SILTY SAND	POORLY GRADED, FINE TO VERY FINE TRACE SILT, GRADING FROM ORANGE TO TAN TO LIGHT GRAY W/ BLACK LAMINAE THROUGHOUT CONSISTING OF V. FINE SAND
75-77	25, 21, 27, 49	SILTY SAND / SAND	75-76.5' SAME AS ABOVE 76.5' SAND - SAME AS ABOVE WITH A SLIGHTLY COARSER GRAIN, BUT STILL FINE
80-82	17, 24, 26, 30	SAND	80-81' WELL GRADED, FINE TO COARSE GRAIN, LITTLE SILT, MEDIUM DENSE, BROWN TO TAN ORANGE 81' - SANDY CLAY, FINE TO COARSE, TRACE BLACK GRAVEL, TAN W/ ORANGE LAMINAE.
85-87	18, 27, 33, 44	SAND	FINE TO VERY FINE, LIGHT GRAY TO TAN W/ ORANGE LAMINAE TRACE CLAY IN THIN LAMINAE VERY DENSE.

COMPUTATION SHEET

BCM

Sheet Number 3 Of 3

Date

Job Number

Computed by Checked by

Name of Client

Project

Description

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
90-92'	21, 25, 30, 31	SAND	SAME AS ABOVE
95-97'	15, 28, 38, 44	SAND	POORLY GRADED, AS ABOVE W/ OCCASSIONAL ZONES OF COARSE SAND W/ RED STAINING
100-102'	45, 50/4"	SAND	FINE GRAIN, POORLY GRADED, OCCASIONAL WHITE CLAY LAMINAE ORANGE-TAN
104-106	17, 25, 27, 50	CLAY	104-105 CLAY (CH) TAN TO BROWN W/ RED LAMINAE 105-106 CLAY AS ABOVE, BLACK TO DARK GRAY, DENSE, HARD, OCCASIONAL V. FINE SAND LENSES ABOUT 1/4" THICK
110-112'	31, 35, 42, 48	CLAY	110-111.2' - DARK BROWN CLAY, SILTY W/ BROWN + BLACK ORGANIC FRAGMENTS 111.2' - SAPROLITE - WEATHERED CHLORITE SCHIST

DB#12 COMPUTATION SHEET

BCM

Sheet Number 1 Of 3

Date

Job Number

Computed by Checked by

Name of Client USX FAIRLESS WORKS

Project DEEP BORING #12

Description

Depth of Split Spoon	SPT Blows per 6"	Soil type	Description
4-6'	12, 13, 13, 12		NO RECOVERY
9-11'	6, 7, 6, 7	SILTY SAND (SM)	WELL GRADED, FINE TO COARSE GRAIN SAND + SUBROUNDED PEBBLES, ORANGE BROWN, WET.
14-16'	7, 12, 15, 19	SAND (SP)	POORLY GRADED, FINE TO VERY FINE GRAIN, TRACE MEDIUM GRAIN, TRACE COARSE, LOOSE WET, ORANGE BROWN SAND
19-21'	3, 5, 9, 9	SILT (ML)	DENSE, MEDIUM GRAY, NOT COHESIVE TRACE FINE SAND.
24-26'	4, 5, 10, 4	SILT	24-25.3 SILT - AS ABOVE RED TAN COLOR, DENSE 25.3' - SILTY SAND (SM) FINE TO VERY FINE SAND, LIGHT GRAY, MEDIUM DENSE WET.
29-31	7, 7, 8, 8	SAND (SM)	SILTY, POORLY GRADED, FINE TO VERY FINE GRAINED, LIGHT GRAY CHANGING TO ORANGE + TAN, WET, BLACK VERY FINE GRAINS THROUGHOUT.
34-36'	4, 10, 10, 11	SAND (SM)	FINE GRAIN, POORLY GRADED, LAMINATED TAN + BLACK OVER LIGHT GRAY OCCASIONAL CLAY LAMINATED LIGHT TAN, MEDIUM DENSE.
39-41	3, 5, 9, 10	SAND	39-39.5' SAND AS ABOVE 39.5' CLAY (CH), LIGHT GRAY w/ ORANGE LAMINAE, COHESIVE, STIFF TO VERY STIFF.
44-46	1, 7, 11, 15	CLAY	LIGHT GRAY w/ RED MOTTLING TRACE FINE SAND, VERY STIFF

DB # 11

BCM DB#11 **COMPUTATION SHEET**

Sheet Number ~~2~~ 1 Of 2
Date
Job Number
Computed by Checked by

Name of Client USX FAIRLESS WORKS
Project DEEP BORING #11
Description ELEVATION = 20.1 FT MSL

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
4-6'	4, 3, 1, 1	CINDERS	4-4.5' CINDERS: BLACK, WET, FINE TO COARSE SAND & GRAVEL 4.5' SAND (SP) FINE TO VERY FINE GRAIN, LITTLE PEBBLES, BROWN & MOIST * TIP IS WET AT 6'
9-11'	1, 1, 1, 1	SILTY SAND	DARK GRAY, FINE GRAIN, WELL SORTED POORLY GRADED SAND (SM) 9.41-10.4' SILT: DARK BROWN, PLASTIC PROBABLY MIXED WITH CLAY, MOIST (MH) 10.4' AS ABOVE - BLACK, ORGANIC, MOIST W/ ORGANIC ODOR.
14-16'	4, 5, 3, 2	SILTY SAND	FINE GRAIN SAND, ROUNDED PEBBLES (10%), BLACK, SLIGHT PETROL ODOR BUT NO SHEEN. SLIGHT SHEEN IN BUCKET AFTER DECON.
19-21'	1, 2, 3, 2	SILTY SAND	19-19.3' SILTY SAND (SP). FINE GRAIN, TRACE MED + GRAVEL BLACK, PETROL ODOR 19.3' SILT (ML): ORGANIC - ROOT FRAGMENTS, BROWN, TRACE SAND GRADES TO BLACK SILT AT BASE MOIST ORGANIC ODOR - SLIGHT SULFUR
24-26'	3, 6, 9, 8	SAND	24-24.3' SAND (SP) POORLY GRADED, FINE GRAIN, BLACK, WET 24.3' GRAVEL AND SAND (GW) FINE TO COARSE SAND, WELL ROUNDED PEBBLES, DARK GRAY TO BLACK
29-31'	14, 15, 14, 16	SAND	FINE TO MEDIUM GRAIN, DARK GRAY, SAND WITH <5% ANGULAR GRAVEL

BCM

COMPUTATION SHEET

Sheet Number 3 Of 3

Date

Job Number

Computed by Checked by

Name of Client

Project

Description OPT #9

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
105-107	14, 16, 14, 21	SANDY	105-105'8" YELLOW-LGT GRAY, MEDIUM-FINE GRAIN GRADED SAND
		SILTY CLAY	105-8" - DK GRAY, STIFF, SILTY CLAY
110-112	12, 15, 16, 23	CLAY	LGT GRAY & RED CLAY WITH LITTLE TO NO FINES. MEDIUM STIFF
115-117'	9, 19, 27, 37	CLAY	RED & GRAY MOTTLED, STIFF CLAY W/ LITTLE TO NO FINES
120-122'	16, 28, 44, 50/5"	CLAY	SAME AS ABOVE
125-127	13, 24, 34, 44	CLAY	SAME AS ABOVE.
130-132	9, 19, 23, 39	SAPROLITE	RED, LIGHT GRAY CLAY, VERY STIFF W/ CONCRETIONS (RELIC STRUCTURE) AND SHARDS OF QUARTZ.

CLAY

DB#4 COMPUTATION SHEET

BCM

Name of Client USX - FAIRLESS WORKS

Project CPT / DEEP BORINGS

Description CPT #9

Sheet Number 1 Of 3

Date BORING DONE 1/4/95

Job Number

Computed by ______ Checked by ______

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
4-5	4, 5, 9, 11	SILTY SAND	DK BROWN - RED BROWN SILTY ORGANIC RICH SAND W/ ONE LAYER OF SILTY CLAY AND GRAVEL
9-11'	1, 2, 3, 3	SILTY CLAY	LGT BROWN, SILTY CLAY SILT CONTENT VARIES [illegible]
14-16'	5, 5, 3, 4	SILTY SAND	DK BROWN, SL VERY FINE GRAIN - FINE GRAIN SAND W/ SILT AND SUBANGULAR - ROUNDED, MED - COARSE GRAIN GRAVEL
19-21'	[illegible]	SAND + GRAVEL	SAME AS ABOVE (14-16') WITH GRAVEL (40-50%)
24-26'	5, 6, [illegible], 7	SAND + GRAVEL	LGT BROWN, MED - FINE GRAIN SAND W/ FINE GRAIN, SUBANGULAR - ROUNDED GRAVEL
29-31'	5, [illegible]	CLAY	TAN/RED MOTTLED MEDIUM CLAY W/ NO FINES OR SAND.
34-36'	6, 9, [illegible], 17	SANDY CLAY	LIGHT GRAY CLAY W/ FINE GRAIN SAND (30-50%)
39-41	3, 4, 6, 7	CLAYEY SAND	LGT GRAY FINE GRAINED SAND W/ VARIABLE CLAY CONTENT (20-[illegible]) W/ RED - YELLOWISH COLOR
44-46	[illegible]	CLAY	RED, YELLOW & LGT GRAY CLAY NO FINES OR SAND - SOFT
47-51	[illegible], 8, [illegible], 12	CLAY	SAME AS ABOVE W/ LITTLE FINE GRAIN SAND
51-53	[illegible], 21	CLAY	RED [illegible] GRAY MOTTLED CLAY W/ [illegible] FINE GRAIN SAND
55-57	[illegible], 9, [illegible], 18	CLAY	LGT [illegible] CLAY W/ SOME RED STREAKS CONTAINS SILT & LITTLE SAND [illegible]

SILTY SAND + CLAY

SAND + GRAVEL

CLAY

SANDY CLAY

CLAY

DB #8

BCM

COMPUTATION SHEET

Sheet Number 3 of 4
Date 11/3/94
Job Number
Computed by ____ Checked by ____

Name of Client USX Fairless Works
Project Deep Boring 8
Description

SPOON | DESCRIPTION

99-101'
N=40
Sandy Clay (CL): light gray turning medium gray, occasional lenses of clayey sand, very fine grain, light gray; clay is very tough and dense.

101-103 Shelby tube
dk gray silty clay - somewhat organic

104-106'
N=57
Sandy Clay (CL): as above - dk gray organics
(105.8'-) Sand (SP): very fine grain, trace clay, lt gray

109-111'
N=50/4"
Sand (SP): fine grain, poorly graded, clean light gray turning yellow/brown with trace silt.

114-116'
N=50/4"
Sand: (SP) fine grain, poorly graded, trace silt, tan, ~~[illegible]~~

* 119-121'
N=73
Sandy Clay (CL): very fine sand and silt? very dense, light gray

MIDDLE CLAY

124-126'
N=45, 50/3"
Clayey Sand (SC) fine grain, light gray black laminae, yellow stains,

129-131'
N=46
(129-129.5') Clayey Sand (SC): medium, some fine grain, light gray
(129.5'-130) Clayey Sand (SC) fine grain, light gray
(130- Sandy Clay: very fine sand, dense light gray (CL)

134-136'
N=75
(134-135.8') Same as above (CL)
(135.8- Clay: light gray, very dense, trace very fine sand (CH)

139-141'
N=54
(139-140.5) Sandy Clay: fine grain sand (40%) light gray
(140.5- Sand: (SP) fine grain, poorly graded, trace clay or silt, light gray

...AVEL

* 144-146'
N=75
Sand: as above with tan coloring

COMPUTATION SHEET

BCM

Sheet Number	1 of 4
Date	11/3/94
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Computed by	STW
Checked by	

Name of Client USX Fairless Works

Project Deep Boring 8

Description

SPOON — DESCRIPTION

FILL

4-6'
N=10 — Sand: fine grain, trace medium grain, poorly graded, clean, light tan w/ orange, loose, moist (SP)

~~6-8'~~ 9-11'
N= 8 — Sand: as above, light gray with black fine grains, black lens at 9.2', moist, loose, clean (SP)

HOLO'CENE

*14-16' (14-14'8") Silty Sand (SM): Dark Gray to Black, fine grain, poorly graded, wet
N=2

*TOC, Cation (14'8"-) Silty Clay (CL): Dark Brown, organic material thruout.

TRENTON GRAVEL

* 19-21'
N=8 — Clay (CH): Brown turning silty and green-gray color at 20' (CL)

24-26'
N= 10 — Clay (CH) - RED BROWN w/ tan mottling

27' — Driller comments - entering Sand & Gravel -

29-31'
N=4 — Sand: (SW) well graded, trace rounded pebbles, dark brown w/ black fine grains, clean, mixed source rock

34'-36'
N=21 — Silty Sandy Gravel (GW) well graded, gravel is well rounded, gray to brown

*39'-41' (39-39'4") Silty Sandy Gravel (GW): Arkose ss and rounded quartz gravel, ~~finer than above~~ up to 2"
N=16

(39'4"- Sand: poorly graded, fine grain, trace medium, trace silt, gray brown, fine grain sands are black

?

44-46' (44-44.7') Silty Sandy Gravel (GP) poorly graded, sand predominately fine grain, gravel subrounded quartz, Brown
N= 34

OLD BRIDGE

(44.7'- Sand: fine grain, poorly graded, clean, lite tan

DB #7

BCM

COMPUTATION SHEET

Sheet Number 2 of 3

Date 12-27/94

Job Number

Computed by ____ Checked by ____

Name of Client USX Fairless works

Project CPT / Split Spoon

Description CPT #7

Depth of Split Spoon	# of Blow counts	Soil Type	Description
55-57	27, 35 50/5"	Sand	Yellow-white w/ orange staining, fine grained, poorly graded sand
60-62	18, 24, 27, 30	Sand	yellow-white sand (same as above 55-57) with lenses of lgt grey clay (1/2" scale).
65-67	40, 50/5"	Sand	yellowish orange, fine grained poorly graded sand w/ lenses of v. fine grained sand (>1/8" scale)
70-72'	30, 42, 50/5"	Sand	yellowish-orange, fine grained poorly graded w/ some orange staining
75-77	20, 23, 25, 33	Sand	Yellowish orange, fine-medium grained sand w/ some orange staining
80-82'	12, 16, 26, 35	clay	Lgt. grey clay w/ silt + v. fine grained sand.
85-87	39, 50/5"	Sand	yellow-white fine-medium grained w/ little-no clay.
90-92'	9, 18, 29, 34	Sandy clay	lgt grey, yellow, & red mottled clay w/ much sand (40-50%). STIFF
95-97	12, 17, 18, 26	sand + clay	lgt grey sand + clay. Soil composition is variable and ranges from (30-60%) clay within a lgt grey fine grained sand
100-102	19, 20 21, 26	Sandy clay	Lgt grey ~~with~~ clay with (20-40%) sand. Soil also contains lenses of yellowish orange fine grained poorly graded sand (1-2" scale)

DB #6

COMPUTATION SHEET

BCM

Sheet Number 3 of 3

Date 12/20/94

Job Number

Computed by ______ Checked by ______

Name of Client USX FAIRLESS WORKS

Project CPT/(SPLIT SPOON)

Description CPT # 6

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
115-117'	35, 2, 26, 27	SAND	lgt grey, graded (fine - med grained) and contains lenses of sandy clay (1-2" scale).
120-122	~~50~~ 15, 26 39, 45	SANDY CLAY	120 - 120'3" Blk - dk Brown clay w/ fine grained sand (40-50%). 120'3" - silty clay lgt grey silty clay (stiff) w/ little - some f grained sand (20-30%)
123-125	17, 29 32, 42	clay	Red + grey mottled clay w/ decomposed wood.
130-132	8, 12, 20, 40	clay	clay w/ variable sand content lgt grey + olive green.
135-137	17, 27, 50/3"	sand	lgt grey, fine grained sand w/ lenses of sandy clay (med - grey).
140-142	46, 50/4"	sand + clay	Blk - dk grey sandy clay grading into a fine grained poorly graded clayey sand (lgt grey).
~~145-14~~			
145-147	27, 50/5"	Sapprolite	Grey and white weathered rock (angular quartz and mica).

DB #6

DB#6

BCM

COMPUTATION SHEET

Sheet Number 1 of 3
Date 12/20/94
Job Number
Computed by ____ Checked by ____

Name of Client USX Fairless Works
Project CPT/Split Spoon borings
Description CPT #6 Boring log

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
4-6'	3, 6, 13, 19	FILL	SLAG
9-11'	10, 12, 14, 16	FILL	SLAG
14-16'	7, 3, 3, 5	SLAG + CLAYEY SAND	14-14'6" SLAG 14'6"-15'4" SAND FINE GRAINED, POORLY SORTED OF VARIABLE COLOR (BLK, LGT GREY, TAN) W/ LENSES (1/4" SCALE) OF CLAY.
19-21'	4, 3, 4, 4	SAND	DK. BROWN, SILTY SAND (FINE GRAINED) W/ LITTLE GRAVEL (FINE-MEDIUM GRAINED).
24-26'	1, 3, 5, 7	SAND	BLK - OLIVE GREY SAND W/ SILT NO GRAVEL.
29-31'	7, 7, 7, 5	SAND	DK BROWN, WELL GRADED, COARSE - FINE GRAINED SAND W/ LITTLE GRAVEL.
34-36'	2, 4, 6, 6.	SAND + GRAVEL.	DK BROWN, WELL GRADED SAND W/ MED FINE SUBROUNDED GRAVEL.
39-41'	4, 5, 5, 6	SAND + GRAVEL.	SAME AS ABOVE. (34-36')
44-46	6, 10 12, 10	SAND + GRAVEL	SAME AS ABOVE (34-36').
49-51	6, 9, 10, 12	SAND + GRAVEL	SAND HAS SILT AND IS TAN. GRAVEL IS FINE AND THERE IS LITTLE OF IT.
55-57	6, 8, 7, 8	SAND + GRAVEL.	TAN - FINE TO COARSE, ~~yo~~ GRAINED. WELL GRADED SAND W/ GRAVEL (FINE-MED GRAINED) SUBROUNDED. ROUNDED.

DB #5

BCM

COMPUTATION SHEET

Sheet Number 3 of 4
Date 12/20/94
Job Number
Computed by PLN Checked by

Name of Client USX FAIRLESS WORKS
Project CPT (SPLIT SPOON)
Description CPT #5

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
95-97'	24, 28, 50/5"	CLAYEY SAND	LGT GREY, FINE SAND W/ LENSES OF SILTY CLAY
100-102	~~CLAY & SAND~~ 27, 50/5"	CLAY & SAND	LENSES (1" SCALE) OF CLAY & WELL GRADED SAND (MED - FINE) W/ OCCASSIONAL FINE GRAVEL & BITS OF DECOMPOSED WOOD.
105 107	13, 23, 39, 22	CLAY	MULTI COLORED STREAKS (WHITE, RED, YELLOW + BLACK) IN A LGT GREY CLAY W/ BLACKS BITS OF DECOMPOSED WOOD.
110-112	~~C~~13, 30, 30, 41	CLAY	LGT GREY W/ SOME STREAKS OF TAN. CONTAINS SOME FINE GRAINED SAND.

CLAY

DB#5

DB#5

COMPUTATION SHEET

BCM

Sheet Number 1 of 4
Date 12/30/94
Job Number
Computed by PCN Checked by

Name of Client USX FAIRLESS WORKS
Project CPT (SPLIT SPOON)
Description CPT #5

DEPTH OF SPLIT SPOON	# OF BLOW COUNTS	SOIL TYPE	DESCRIPTION
4-6'	2, 4, 4, 5	FILL	SLAG
9-11'	10, 3, 15, 9	FILL	SLAG
14-16'	1	SILT	DK BROWN, ORGANIC RICH SILT W/ LITTLE FINE GRAINED SAND.
19-21'	2, 2, 4, 6,	SILTY SAND	LGT BROWN, WELL GRADED (MED-FINE) GRAINED, MULTI-COLORED GRAINS OF SAND W/ 20-40% SILT.
24-26	4, 4, 14, 14	SAND + GRAVEL	LGT. BROWN, MED FINE GRAINED, WELL GRADED SAND W/ FINE-MEDIUM GRAVEL.
29-31	10, 8, 8, 8	SAND + GRAVEL	SAME AS ABOVE (24-26')
34-36	8, 12, 6, 6	SAND + GRAVEL	SAME AS ABOVE (24-26')
39-41	1, 2, 10, 10	SILTY SAND + GRAVEL	DK. GREY SAND W/ ORGANIC RICH SILT + CLAY. OCCASSIONAL FINE GRAVEL.
44-46	50/5"	SAND	WHITE, LGT GREY, FINE GRAINED, POORLY ~~GRADED~~ GRADED ~~SORTED~~ W/ LITTLE CLAY (10-20%)
			> DRILLER STATES THIS TRANSITION OCCURS @ 43'
49-51'	10, 28, 33, 34	SAND	SAME AS ABOVE (44-46') W/ STREAKS OF ORANGE + BLK
55-57	16, 39, 36, 44	SAND	LGT GREY W/ ORANGE STAINING, POORLY GRADED, FINE GRAINED, W/ OCCASSIONAL LENSES OF LGT GREY CLAY W/ BLK STREAKS

TRENTON GRAVEL

BRIDGE

DB #4

BCM

COMPUTATION SHEET

Sheet Number 2 of 3
Date 12/14/94
Job Number 005039 7012
Computed by PCN Checked by

Name of Client USX FAIRLESS WORKS
Project CPT (SPLIT SPOON)
Description CPT #4

DEPTH	SOIL TYPE	DESCRIPTION
55-57 ~~47-49~~	SAND	LGT GREY W/ ORANGE STAINING, FINE GRAIN, POORLY GRADED, SUBROUNDED W/ VERY FINE BLACK GRAINS
60-62 52 54	SAND	SAME AS ABOVE W/ GREY STREAKS THROUGHOUT
65-67 57 59	SAND	LGT GREY W/ DK BROWN + BLACK STAINING FINE GRAINED, POORLY GRADED
70-72 62 64	SAND	SAME AS ABOVE - STAINED BLACK ON THE OUTSIDE + THROUGHOUT.
75-77 67 69	CLAY	LGT GREY W/ LITTLE FINE GRAINED SAND (~20%). STIFF.
80-82 72 74	CLAY	LGT GREY W/ SMALL, (FINE GRAINED) PIECES OF BLACK CHARCOAL AND SAND (~10%.)
85-87 77 79	CLAY	LGT GREY W/ LITTLE FINE GRAINED SAND + SILT.
90-92 82 84	SILTY CLAY	LGT GREY W/ STREAKS OF FINE GRAINED SAND (ORANGE + RED IN COLOR).
95-97 ~~87 89~~	SANDY CLAY	95-96'5" SANDY CLAY - LGT GREY ~~IN~~ CLAY W/ VERY FINE GRAINED SAND. 96'5"-97' GREY, RED, YELLOW MOTTLED CLAY W/ CHUNKS OF SAND THROUGHOUT. STIFF
97-99 89 91	SANDY CLAY.	97-98 SAME AS ABOVE (95-96'5") 98-99 SAME AS ABOVE (96'5"-97')
100-102 92 94	~~LGT~~ SANDY CLAY	100-101 SAME AS ABOVE (95'-96'5") 101-102 SAME AS ABOVE (96'5"-97').

(Left margin, partly cut off:) ...D ...IDGE ... IIDDLE ...LAY

COMPUTATION SHEET

Sheet Number 2 of ____
Date 12/12/94
Job Number 0050397012
Computed by PCN Checked by ____

...nt USX Fairless Works
...ct CPT (SPLIT SPOON)
Description CPT #3

DEPTH	CLASS	MATERIAL	DESCRIPTION
~~SAND~~ 110 – 112'		SAND	yellow w/ orange staining ~~and~~, ~~+~~, fine grained w/ lenses of v. fine grained black sand.
		110' 10"	clay content increases from 0 to 80%. Clayey sand is grey in color.
115'-117'		sand	F. grained, poorly graded yellow sand w/ orange staining.
120-122"		SAND	same as above except color is orange.
125-127'		SAND	yellow orange, poorly sorted med-fine grained sand.
130'-132'		sand	lgt yellow, well graded, subrounded fine to medium grained sand. Grades to grains of black (mica), pink + red color. Last 4" contain grains of lgt grey, medium, well sorted sand and a 2' plug of grey clay.
133-135		Clay	- Sapprolite lgt grey + red mottled w/ v fine grained sand + mica grains.

End of Boring

DB-3

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DB#3 1/3

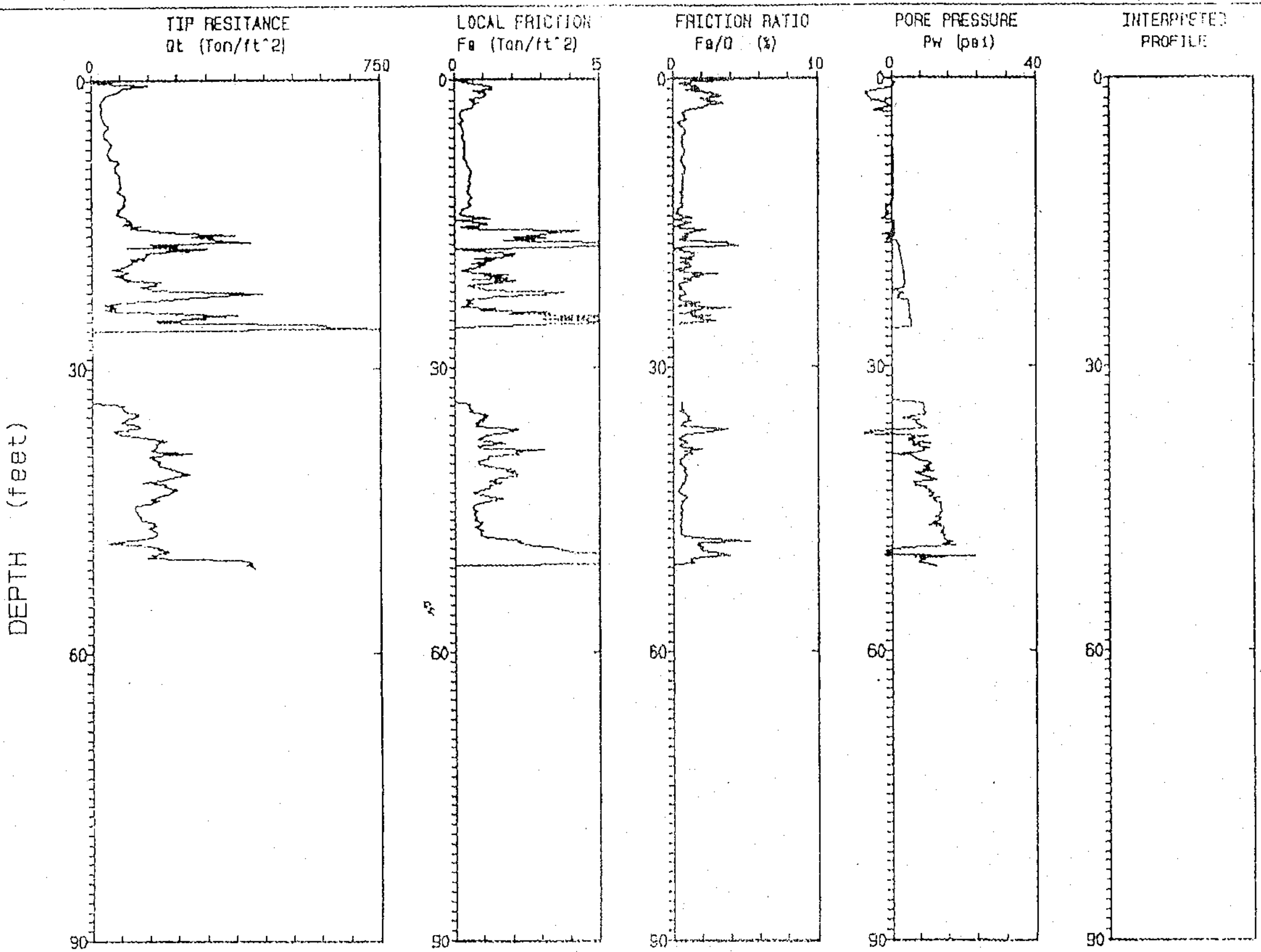
BCM

Operator : CONETEC
Location : USX

CPT Date : 12:08:94 12:34
Cone Used : 10 TON A 009

Sounding :
Job No. : CPT-3A

Pg 1 / 4



Depth Increment : .05 m

Max Depth : 51.02 ft

DB # 2

BCM

COMPUTATION SHEET

Name of Client: USX - Fairless Works
Project: Deep Boring Location #2
Description:

Sheet Number 1 of 2
Date 11/2/94
Job Number
Computed by STW Checked by

Spoon	Description
0-2'	Sand: well graded, dark brown (SW)
2-4'	Sand: poorly graded, dark brown (SP) fine grained
4-6'	Sand: as above (SP)
6-8'	Sand: as above, lighter brown, wet tip (SP)
8-10'	Skipped —
10-12'	Sand: fine grained, poorly graded, brown (SP)
12-14'	Sand: w/ clay well graded, medium to coarse grain, with subrounded quartz pebbles and angular, black gravel, (SW)
15-17'	Sand: silty sand and gravel, well graded, brown (SW)
19-21'	(Gravelly) Sand: well graded, subrounded quartz pebbles brown with black fine sand (SW)
* 24-26' TOC, Cation	Clayey Sand: poorly graded, fine to very fine grain, light gray to tan, trace clay (SP)
29-31'	Sand: as above, color changes to orange/tan (SP) fine - no clay
34-36'	Sand: as above (SP)
39-41'	Sand: as above (SP) w/ occasional gravel
44-46'	(44-45') Sandy Clay: (CH) light gray to tan, fine sand
	(45-49') Sand: poorly sorted, fine grain, gray (SP)
49-51'	(49'-54') Clay: (CH) light gray, trace fine sand
54-56'	(54-54.5') Clayey Sand: (SC) fine grain, light gray
	(54.5- Sand: (SP) fine grain, poorly graded, trace silt or clay, light gray w/ orange

OLD BRIDGE

MIDDLE CLAY

BCM

COMPUTATION SHEET

Sheet Number 2 Of 3
Date 1/5/95
Job Number
Computed by ______ Checked by ______

Name of Client USX Fairless Works
Project Deep Boring/CPT #1
Description

Depth of Split Spoon	SPT Blows per 6"	Soil Type	Description
60-62'	10, 16, 20, 20	Clay	light gray w/red and orange staining, CH, cohesive, plastic, dense with occasional sand zones
65-67'	9, 16, 38, 21	Clay	Same as above: Red grading into gray and orange sandy @ base
70-72'	26, 32, 37, 48	Sand	gray to orange, fine to medium grained sand with trace clay. Occasional lenses of clay/sand to sandy clay
75-77	10, 36, 38, 50/5"	Clay - Sand -	75-75.5' Clay - CH, light gray trace of very fine sand 75.5'-77 Sand very fine to fine (SP), trace clay, light gray with black very fine grains occasional sandy clay zone ≈2" thick)
80-82'	12, 26, 36, 50/5"	Sand & sandy clay	Sand & sandy clay - as above seems to fine upwards fine to very fine sand to sandy clay to clay
85-87'	30, 30, 30, 32	Sand	light gray, fine, trace clay black laminae
90-92'	27, 34, 50/5"	Sand	light brown, med to very fine, subrounded sand (SW)
95-97'	9, 10, 12, 13	Clayey Sand	Coarse to fine 95.5-96' - medium to fine, lt gray, some clay "clayey sand" 96' - Clay tan to red w/red angular accretions - upper zone to light gray clay, continue

Margin notes: 70-18 / 52 (beside 70-72); 96-18 / 78 (beside 95-97)